HY-FAH: An Indoor Hydroponic System with Remote Monitoring and Regulation Using Convolutional Neural Network Application for Crop Status and Plant Growth

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I. Introduction

With the population continuously expanding, pushing further the tendency of more urbanization projects in the future, it is necessary to develop innovative ways of producing enough food to accommodate the basic needs of the people. Hydroponics is a type of horticulture that has become beneficial recently with its highly efficient use of resources. In this technique, plants are grown in an environment without soil. Instead, they are submerged in a nutrient-rich water solution. Compared to soil-grown plants, hydroponic plants can grow more quickly and yield greater quantities [1]. The reason for this is that plants can grow more effectively since they have access to a precise balance of water and nutrients.

Plants produced from dirt have lower quality due to pollutants and illnesses. As soil includes pollutants and diseases, the plants grown in systems using nutrient-rich solutions are free from these factors. Controlled Environment Agriculture (CEA) is a high-tech hydroponic method of optimizing horticultural operations. Hydroponics and other dynamically controlled environment agriculture, combined with emerging agriculture technology interventions, offer practitioners and scientists opportunities to ask new questions and develop novel solutions that maximize food production while minimizing economic costs and environmental externalities.

II. Background of the Problem

The Philippines is one of the 63 countries with the largest number of undernourished people. In the years 2019 to 2021, FAO reported that 5.3 million Filipinos were severely food insecure, while 48 million fell under the category of moderate or severe food insecurity. According to FAO, the factors at play in food insecurity are the triple crises of climate, long-standing conflicts, and the COVID-19 pandemic [2]. The geographical features and location of the country heightened its vulnerability to the impacts of climate change and weather events in general. With an average of 20 typhoons a year, the agricultural sector is adversely impacted, affecting the availability, affordability, and accessibility of nutritious food. However, apart from the economic and environmental factors that contribute to food insecurity and malnutrition in the country, they are also driven by the technological aspect of the country's agriculture with its antiquated farming methods and the negative effects of urbanization in the form of land conversion. FAO director-general QU Dongyu stated that we need the transformation of agri-food systems for better production, nutrition, the environment, and a better life for all [3]

To contribute to food security and improved nutrition, the researchers present an innovative system allowing urban residents to produce hands-free leafy vegetables with optimized yield inside their houses. With the use of hydroponics, an efficient soilless farming method, leafy vegetables can be grown in a system that consumes minimal space suitable for indoor use. The growing, monitoring, and harvesting processes are automated to minimize

manual labor and to ensure the good quality of its yield. Implementing a rechargeable battery will provide an uninterruptible power supply which is crucial for the continuous control of the nutrient-rich solution.

III. Objectives

The general objective of the study is to design an Indoor Hydroponics System with Regulation using Convolutional Neural Network Application for Crop Status and Plant Growth, which allows a sustainable and energy-efficient environment and hands-free farming of high-quality leafy vegetables.

This research journal aims to develop a monitoring system for the crop status using Raspberry Pi with cameras and Yolov5 model to determine when the plants are already good for harvest.

It also aims to develop a notification system that will enable the user to remotely monitor the environmental parameters (pH level, Total Dissolved Solid (TDS), and air temperature) and the crop status with the use of mobile application and Internet of Things.

IV. Related Literature

` The study, "Fully Automated Hydroponic System for Indoor Plant Growth", developed an automated hydroponics system called the "Titan Smartponics" which utilized Arduino, Raspberry Pi and IoT technology for remote monitoring and control of the parameters such as electrical conductivity, pH level, water level, temperature, and humidity in the system. The sensors provided inputs for the system to control and keep the parameters stay in the desired range. The proponents of the study aimed to create the system in a way that it requires no human interaction aside from the manual placement of germinated plants. A mobile application was also developed in order to allow monitoring and control through smartphones. As a result, the system was able to help plants grow healthier through monitoring and keeping control of the necessary conditions for the plants to grow properly. It was also concluded that pH level is important to be monitored since the parameter is dependent on temperature [4].

The study, "Automated Hydroponics Nutrition Plant Systems Using Arduino Uno Microcontroller Based on Android", developed a hydroponics system contained in a chamber consisting of Arduino Uno as the microcontroller which automated the control of nutrient flow to the plants and sensors for the detection of water level in the tubes and for room temperature detection. An android application was developed for remotely checking the water level and temperature in the system. The microcontroller was used in real-time in order to get the pumps to supply nutrients for the plants at the right time. The findings of the study conclude that hydroponic plants grow well with proper water and nutrient usage which was made efficient through automation. It was also observed that hydroponic plants grow faster compared with soil-grown plants. Further developments were recommended such as the addition of detection of pH solution acidity level, viscosity, and oxygen [5].

The proponents of the study, "Planttalk: A Smartphone-based Intelligent Hydroponic Plant Box", aimed to develop an IoT-based intelligent hydroponic plant factory which intelligence is built through a smartphone. It utilized different parameter sensors in measuring temperature and humidity, pH level, water level, carbon dioxide, and oxygen levels. Automatic LEDs and timer were used as well as actuators for drain and suction pumping, and spraying water and nutrient solutions. The hydroponics chamber is a small box with only one level and compartment. The mobile application developed was used to monitor and regulate the conditions of the plant. Additional features were integrated with the application such as providing options for the users to share IoT devices and flexibly select desired IoT devices to be included or changed in their hydroponic plant boxes. The system was able to effectively decrease CO2 concentration compared to the traditional planting system [6].

V. Methodology

In the first subsystem, the regulation of the nutrient solution and environmental parameters, first, the sensors for the nutrient solution and the environmental parameters (humidity temperature) gather discrete values which are sent to the Arduino Mega. Six sensors will be used to measure the nutrient solution namely the DHT22 for temperature and humidity, the DFRobot TDS Sensor for the estimation of the Total Dissolved Solids, the Float Level Sensor for the liquid level, the pH sensor for the acidity and alkalinity of the solution, the Water Level Sensor for the water level measurement, and the Waterproof Temperature Sensor DS18B20 for temperature measurements in far and wet conditions. The fetched data will be compared to the desired value to properly regulate the balance of the nutrient solution and the required level of temperature and light to grow the hydroponics plants. If the nutrient and light are lower, and the temperature higher than their required values, the DC Pump, LED strips, and the DC Fan will be activated respectively. The data from the sensors will be stored in a database and reflected in the mobile application for remote monitoring.

Simultaneously, In Crop Status and Plant Growth, as well as remote monitoring and regulation, the first step of the process is the capturing of images inside the chamber that will go through image processing using Convolutional Neural Network with the Yolo v5 model. Likewise, these data will be stored in a database and reflected in the mobile application as part of the remote monitoring.

The hydroponic system utilized in this study was constructed while considering the dimensions of an average door of houses in urban areas. The chamber has fixed dimensions of 2 x 0.75 x 1.9 meters. The chamber was assembled using slotted angle bars as its frame and body, and polycarbonate sheets for its walls.

The water, as its growing medium, will be pumped to PVC pipes and clear hoses that were utilized in each side of the hydroponic tubes. Each layer of the system has an allocated space of 0.3302 meters in between. These dimensions of these spaces were fixed in consideration with an average size of fully grown lettuces and for a comfortable working space of the arm.

The AC-powered water pump responsible for pushing water to the tubes is submerged in a 70-liter water reservoir, ensuring continuous water circulation within the system. In addition, direct current (DC) powered devices such as fans, pumps, and grow lights are installed into the chamber to regulate environmental parameters crucial for optimal plant growth and yield. For a continuous supply of energy, a rechargeable battery is incorporated to prevent the system from turning off to avoid the crops from drowning.

VI. Result and Discussion

The system that the researchers created effectively combines automation, remote monitoring capabilities, and hydroponics cultivation techniques. With the help of this technology, environmental parameters like moisture, temperature, and nutrient levels can be precisely controlled, providing the best circumstances possible for crop growth. The capacity of the system to gather and harvest mature plants, as well as remotely monitor crop growth and environmental conditions, is highlighted in the study. The system offers an easy-to-use interface that enables researchers to view real-time data and receive notifications regarding growth phases, and environmental variables.

VII. Conclusion

In conclusion, by considering various environmental parameters in cultivating crops using hydroponic, which led to the development of an automated indoor hydroponics system with remote monitoring with the integration of the YOLOv5 model for crop status, specific conclusions drawn in this study are as follow:

1. The development of an Indoor Hydroponics Garden Chamber provides a promising solution for gardening indoors in urban areas. Grown plants are as rich and nutritious as the soil-based grown plants.

2. The design of a circuit that monitors the environmental parameters. By incorporating various sensors and peripherals such as fans and grow lights required to secure the environmental parameters requirement, the system was able to adjust and justify that hydroponic indoor planting can also be an optimal environment for the plants to grow.

VII. References

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