HY-FAH: An Indoor Hydroponic System with a Fully Automated Harvester

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I. Introduction

Nutritious food is a necessity for a healthy diet to improve an individual's overall health and well-being. Food insecurity and malnutrition go hand in hand as issues that the Philippines has been dealing with for years [1]. Food security is constantly affected by population growth and urbanization. An increasinAg fraction of the population is now experiencing hunger and malnourishment as agricultural fields are transformed to accommodate the changes brought by urbanization. The Philippines has the most food-insecure people in Southeast Asia, recording a total of 59 million Filipinos suffering from a moderate to severe lack of consistent access to food between 2017 and 2019 [2].

Through thorough investigation and research, this study aims to construct an Indoor Hydroponics System with a Fully Automated Harvester, which will allow a sustainable and energy-efficient environment and hands-free farming of high-quality herbs and leafy vegetables.

II. Background of the Problem

Crops are traditionally and frequently harvested by hand. Manual harvesting is particularly common for crops that have wide time periods for optimal maturation or for crops that are offered for direct consumption, despite the fact that it is labor-intensive. Farmers turned out mostly complaining about their inability to find labor. The shortage in terms of labor had started to become a major issue for farmers, especially in states like California [3]. As for the chefs, what they were mostly looking for was quality, of course, but also predictability and consistent quality. Thus, automation is sought out by most in order to lessen manual labor.

This present invention revolutionizes the traditional farming process through the integration of a fully automated harvesting system into the hydroponic system. A fully automated hydroponic harvester has the potential to streamline the harvesting process, reduce labor costs, and increase efficiency. This method doubles plant growth in half the time. This type of harvesting system could use sensors and cameras to gather data from the system and detect whether the plants are ready for harvest and employ a robotic arm to cut and transport them to a processing area.

III. Objectives

The general objective of the study is to design an Indoor Hydroponics System with a Fully Automated Harvester, which allows a sustainable and energy-efficient environment and hands-free farming of high-quality leafy vegetables.

This research journal aims to design and develop a regulation system suitable for indoor use with a rechargeable battery as a backup power supply that will serve as the controlled environment for the hydroponics system.

Also this research also aims to design and develop a system that can automate a single robotic arm that will be used throughout the whole system for harvesting using Arduino MEGA.

IV. Related Literature

The study, “Physical and mechanical properties of hydroponic lettuce for automatic harvesting”, designed an automatic harvester of a hydroponic lettuce while considering the physical and the mechanical properties of the lettuce. Moisture content of stem, root and leaf, geometric characteristics, pulling force, and root cutting force were studied in order to harvest hydroponic lettuce. The cutting force of the roots and the pulling force of hydroponic lettuce were determined by the shear experiment and tensile experiment, respectively. Statistical comparisons show that the leaves have the highest moisture content, but the stems break most easily for short of toughness. The researchers also analyzed the root cutting force of the hydroponic lettuce with different cutting speeds and cutting positions. Concluding that the root cutting force affected the cutting position. The pulling force of hydroponic lettuce was obtained by the tensile experiment having the mean force of 13.03 N.

This study provides valid theoretical support for the design of the automatic harvester of hydroponic lettuce. The results of this study could be used in future designs and of automated harvesting equipment [4].

The study, “A Computer Vision Based Robotic Harvesting System for Lettuce”, proposes a computer vision based robotic harvesting system for lettuce in hydroponic farms. Using the location of the holes in the hydroponic system, the researchers would estimate the location of the lettuce that would be harvested. The locations of holes covered by lettuces are estimated based on uncovered holes and tubes’ edges which are found by using Hough transforms. A robot manipulator and a servo controlled gripper are used for the harvesting task. The concluding results show that the system having the mean location error of 0.83 mm (typical cases) and maximum error of 9.62 mm, can efficiently perform harvesting in real world environments [5].

V. Methodology

The automation of harvesting using the robotic arm and the image capturing and processing will use the Arduino MEGA and Raspberry Pi. Also, the robotic arm used for harvesting would be programmed using Arduino MEGA. The CNN would be able to detect the mature and ready to harvest plant. The system would notify the user first that it will harvest the detected plants before fully executing its activity.

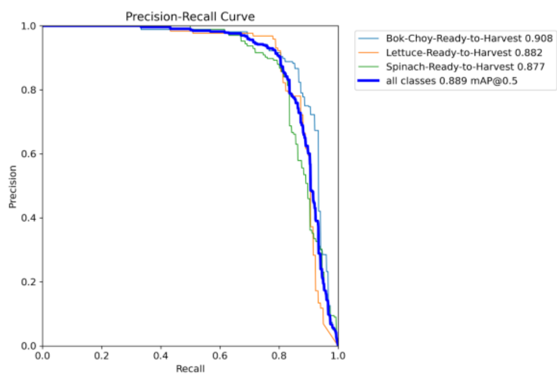
The system's operation is divided into Growing (Hydroponics), and Harvesting. In the Planting process, first, the germinated seeds are placed manually inside the chamber with a hydroponic foam in a cup along with the germinated seed, and place it in one of the holes of the hydroponic tubes. For 3 to 4 weeks, the germinated seeds will develop into full-grown leafy vegetables with the help of the balanced and sufficient nutrients in the solution that will be measured and regulated automatically by the system. In the process of growing, the crops are monitored using image processing. Also, when the growing period is completed and the camera detects a Ready-to-harvest plant, it will be harvested by the robotic arm, gripping the cup as well, and placing them into the harvest outlet located inside the chamber.

With the use of the YOLOv5 Model, the researcher would collect the datasets of the crops. The accumulated data would be stored in a cloud which will allow the researchers to gather valid data and collect data sets from the fully grown plants. Once the data is processed, the data would then be sent to the robotic arm, thus removing the plants that are ready to harvest. A fixed position of the cameras is considered in YOLOv5’s accuracy for the interpretation of the data.

The automated harvester is an open-source based design of a pick-and-place 6

DOF robotic arm attached to a combination of vertical and horizontal gantry. The body of the arm is constructed using 1 kg of PETG filament through 3D printing technology. To pivot the joints to a desired angle, two types of servo motors are used – MG996R for the arm part and SG90 for the gripper part. The programmed sequence of movements of the motors will perform the harvesting feature of the system. Furthermore, to suffice the required scale of functionality of the dimensions of the chamber, a vertical and horizontal gantry aids the movement of a single robotic arm to accommodate the number of plants on all of the four layers. In the vertical gantry, a GT2 pulley belt is used along with a stepper motor to elevate the horizontal gantry to a certain layer of hydroponics tube. In turn, the horizontal gantry also used the timing belt system to aid the robotic arm to reach the plants. The movement of the stepper motors is also programmed for the harvester to reach an accurate position to be able to grip the mouth of the cup with a full-grown lettuce.

VI. Result and Discussion



The figure shows the precision-recall curve of the trained datasets which indicates the performance of the detection model. The dataset comprises a total of 3,166 images of bok choy, lettuce, and spinach that indicates harvest ability and 1,299 images of the plants that do not. The training of image datasets using YOLOv5 resulted in an average precision of 0.889 mAP and 0.751 mAP for the detection of ready and not ready to harvest plants respectively. Precision is a measure of correct predictions for each image instance while recall measures the proportion of image instances that were correctly predicted. The curve illustrates the relationship between the two and considers both measures at various threshold values which helps evaluate the accuracy of the trained model.

A higher mAP@0.5 (mean Average Precision at an Intersection over Union threshold of 0.5) generally indicates high accuracy of a trained model in detection tasks. The resulting trained model was used for detecting the plants in the chamber that are ready and not ready for harvest.

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 automated harvester, specific conclusions drawn in this study are as follow:

1. The utilization of a Convolutional Neural Network (CNN) model for crop status based on captured images has an accuracy of 88.9%. The fully grown plant was accurately detected and sent and notified the user of its availability to be harvested.

2. The real-time data that was sent to the mobile application through Internet of Things (IoT) technology continued to track the hydroponics chamber's environmental conditions including temperature, humidity, pH levels, and nutrient solutions.

3. Development of a robotic arm that will harvest the detected fully grown plant. The incorporated arm will collect all the plants at once and will be placed in the designated area.

VII. References

[1] FAO, IFAD, UNICEF, WFP and WHO. 2020. The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets. Rome, FAO. https://doi.org/10.4060/ca9692en

[2] Baclig C.E., (2022), World Food Day 2022: Rising costs keep millions in PH away from healthy diets. PIDS - Philippine Institute for Development Studies

[3] M. Samangooei, P. SaSSi and A. Iack, “Soil-less systems vs. soil-based systems for cultivating edible plants on buildings in relation to the contribution towards sustainable cities," Future of Food: Journal on Food, Agriculture and Society, vol. 4, no. 2, pp. 24-39, 2016.

[4] W. Wang, Y. Ma, L. Fu, Y. Cui, Y. Majeed, "Physical and mechanical properties of hydroponic lettuce for automatic harvesting". Inf Process Agric (2020), 10.1016/j.inpa.2020.11.

[5] P. Viet-Cuong, N. Hoang-Giap, D. Thanh-Khang, H. Gia-Bao, "A Computer Vision Based Robotic Harvesting System for Lettuce" in International Journal of Mechanical Engineering and Robotics Research, Nov. 11 2020 [Online]. Available: http://www.ijmerr.com/uploadfile/2020/1016/20201016113846679.pdf

[6] A. Isabel Luna Maldonado, J. Mariana Márquez Reyes, H. Flores Breceda, H. Rodríguez Fuentes, J. Antonio Vidales Contreras, and U. Luna Maldonado, 'Automation and Robotics Used in Hydroponic System', Urban Horticulture - Necessity of the Future. IntechOpen, Jun. 17, 2020. doi: 10.5772/intechopen.90438.

[7] Musa, A., Hamada, M., Aliyu, F.M., Hassan, M., (2021), "An Intelligent Plant Dissease Detection System for Smart Hydroponic Using Convolutional Neural Network", Proceedings - 2021 IEEE 14th International Symposium on Embedded Multicore/Many-Core Systems-on-Chip, MCSoC 2021, Institute of Electrical and Electronics Engineers Inc., p.345-351

[8] Haiqing Wang, Shuqi Shang, Dongwei Wang, Xiaoning He, Kai Feng, Hao Zhu (2022), "Plant Disease Detection and Classification Method Based on the Optimized Lightweight YOLOv5 Model", College of Mechanical and Electrical Engineering, Qingdao Agricultural University, Qingdao 266109, China

[9] Nisha, S., Somen, A., Kausha, K., Narendra, S., Chaurasia O.P, "Hydroponics as an advanced technique for vegetable production: An overview"

[10] M. Samangooei, P. SaSSi and A. Iack, "Soil-less systems vs. soil-based systems for cultivating edible plants on buildings in relation to the contribution towards sustainable cities," Future of Food: Journal on Food, Agriculture and Society, vol. 4, no. 2, pp. 24-39, 2016.

[11] 005N.K. Bharti, M. Dongargaonkar, I. Kudkar, S. Das, M. Kenia. (2019). Hydroponics System for Soilless Farming Integrated with Android Application by Internet of Things and MQTT Broker. 1-5. 10.1109/PuneCon46936.2019.9105847.

[12] S. Tagle, H. Benoza, R. Pena, A. Oblea, "Development of an Indoor Hydroponic Tower for Urban Farming" Dept. Mech. Eng., De La Salle University, Manila, Philippines, 2018. [Online]. Available:https://www.dlsu.edu.ph/wp-content/uploads/pdf/conferences/ditech/proceedings/volume-3/paper-10.pdf

[13] V. Palande et al. Fully automated hydroponic system for indoor plant growth. 2017 International Conference on Identification, Information and Knowledge in the Internet of Things. Proc. Comput. Sci. (2018)

[14] Siddiq, A., Tariq, M.O., Zehra, A., Malik, S., **"**ACHPA: A sensor based system for automatic environmental control in hydroponics", Food Sci. Technol 40 (3) • July-Sept 2020 •

[15] Asolkar, P. S., & Bhadade, U. S. (2015, February 26-27). An effective method of controlling the greenhouse and crop monitoring using GSM. In IEEE International Conference on Computing Communication Control and Automation (pp. 214-219). Pune, India: IEEE.