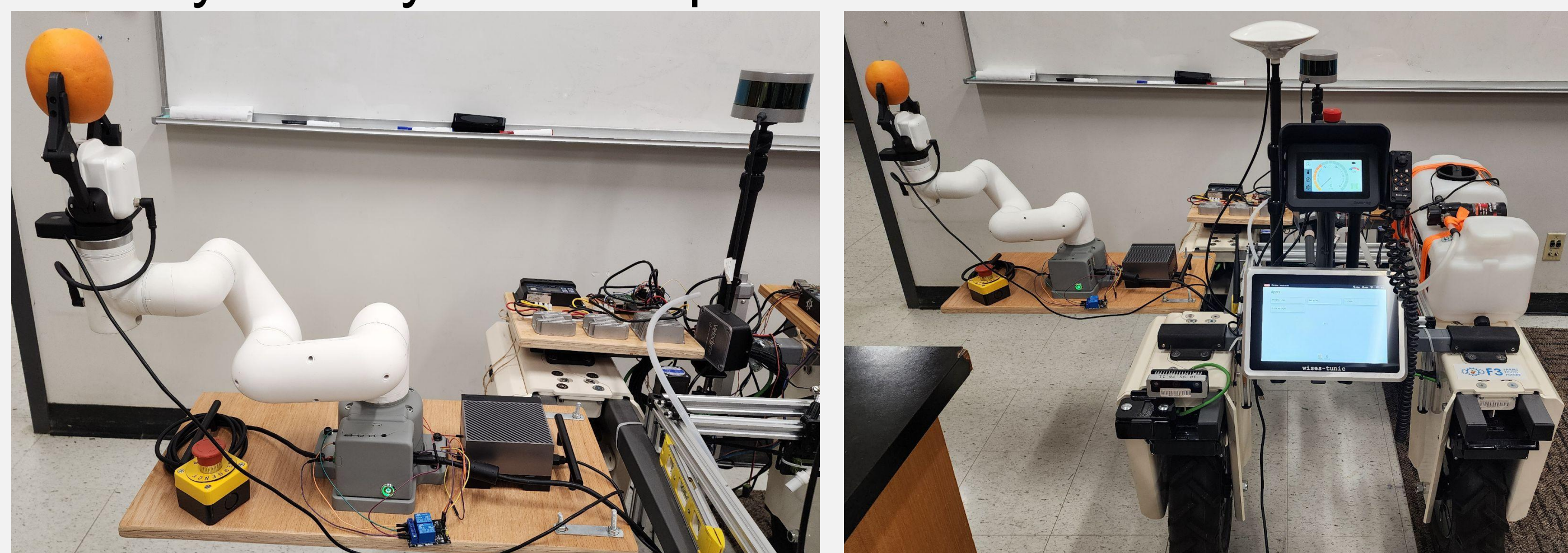


Abstract

Farming represents a multi-aspect effort demanding the consistent and effective execution of numerous tasks. In recent decades, the agricultural landscape has faced alarming global challenges, encompassing depleting water resources, increasing input expenses, and a diminishing agricultural workforce. The emergence of Agricultural Technology (AgTech) in recent years has ushered in a transformative era, enhancing farm productivity while reducing labor-intensive and hazardous activities. Our proposed solution leverages Artificial Intelligence (AI), Deep Learning, RGB and Depth cameras, alongside a Robotic Arm, all seamlessly integrated within a custom designed website framework. This comprehensive integration empowers our system to autonomously execute diverse intelligent farming tasks with precision and efficiency.

Objectives/Applications

The main objective of the Smart Harvesting System is to provide a more efficient and humane way for farmers to harvest their crops. This will be accomplished by training a machine learning model to detect eight kinds of tree fruit, developing software and hardware systems for enabling physical harvesting, developing the front-end and back-end of a custom website, integrating the system into the SARDOG robot, and implementing a way to power the entire system by a mobile power source.



End Effector

The end effector chosen for the arm is a three-finger flexible gripper that is controlled by a stepper motor. The flexible material of the three fingers enables gentle handling of harvested fruits, and the fact that it uses a stepper motor means that it can be powered by the SARDOG batteries and controlled by the Raspberry Pi 5. This is an improvement on the previous end effector version that utilized two non-flexible fingers.

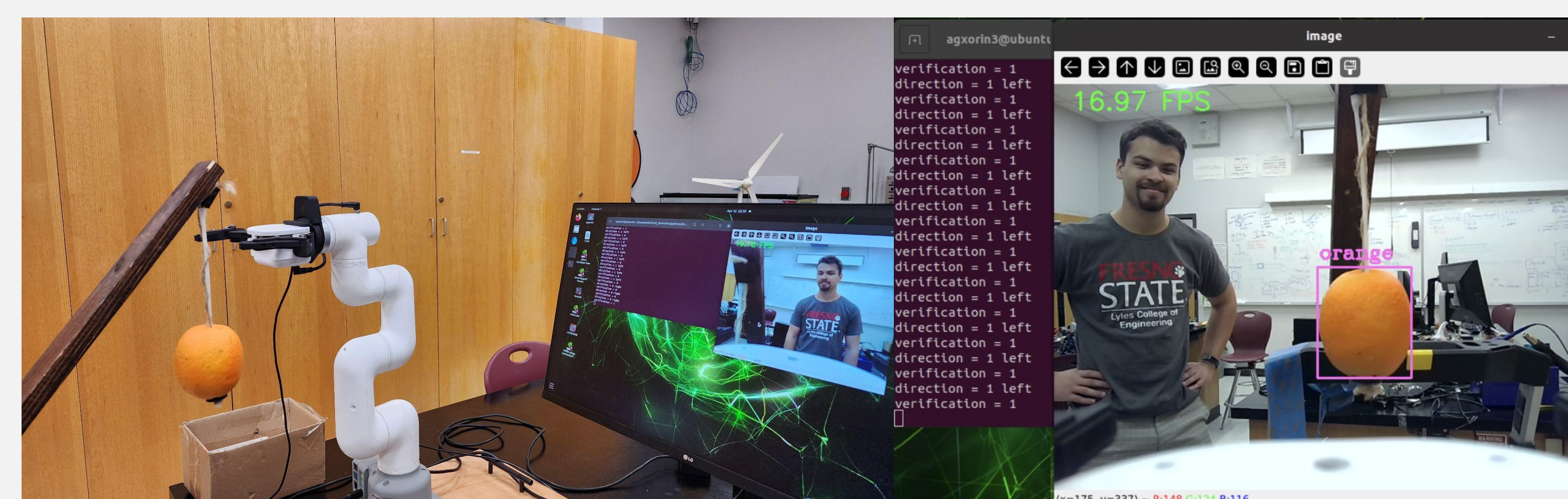


Smart Harvesting

The tree fruit harvesting robotic arm is equipped with a 6-degree-of-freedom (DoF) collaborative robot (cobot) capable of lifting payloads up to 1 kg. Controlled by a Raspberry Pi 5 microcomputer programmed with Python, it receives instructions from a machine learning model via a hardware GPIO connection with the Nvidia Jetson Orin. The Raspberry Pi is used to send angular commands to the servo motors in the robotic arm. Angular commands were chosen over coordinate commands so that the exact motions performed to reach the end point could be customized, since in certain environments the arm must take a non-direct path to the fruit in order to avoid branches and other obstacles.

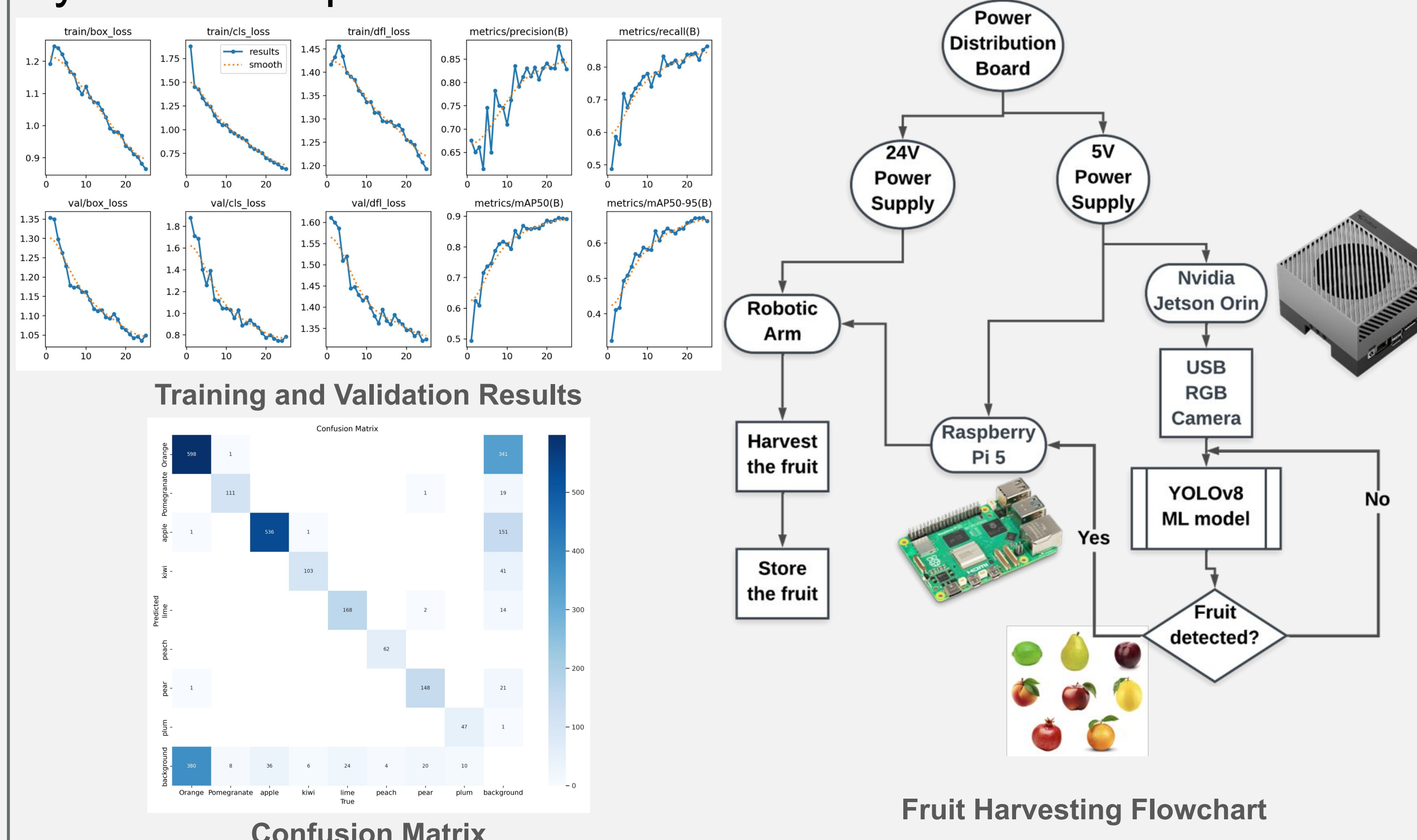


MyCobot320pi Elephant Robotics Arm



The ML model detecting an orange

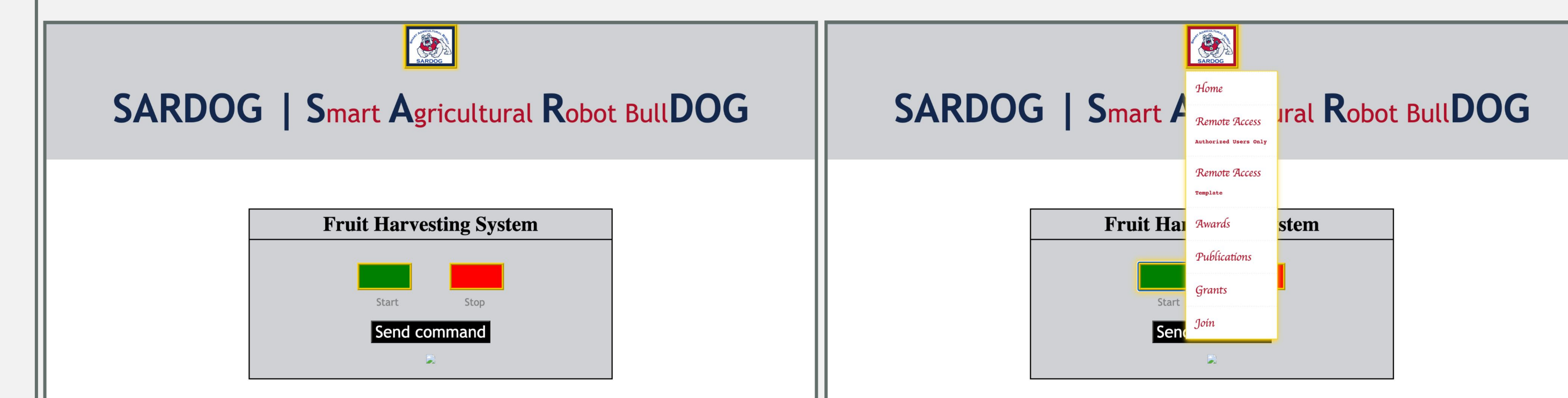
The Jetson Orin is used to separately run the computer vision detection, since it has much stronger GPU capabilities than the Raspberry Pi. The YOLOv8 deep learning model, trained on eight different types of tree fruit, identifies, classifies, and determines the coordinates of the fruit within the camera frame. The model was trained on a custom compiled dataset using Google Colab, and is implemented for real time detection using Python and OpenCV.



Website Control

The website developed for the SARDOG project is used to remotely connect to and control the smart harvesting system.

The Remote Access page of the SARDOG website that is for authorized users only is what is used for remotely accessing both the Jetson Orin and the Raspberry Pi. The website is hosted as a Python Flask app, with the Jetson Orin acting as the server. As long as the Jetson Orin is powered on and running the Python Flask script, the page can be accessed. Simple animated and color-coded buttons are used on the website to start and stop the smart harvesting system.



Remote Access website page for authorized users only

In order to limit access to the remote access page so that unauthorized users can't control the smart harvesting system, a Tailscale network was used. This network allows SSH tunneling between all devices logged into it from any WIFI network in the world at static IP addresses. Currently only team members have access to this Tailscale network.

Conclusion

The Smart Harvester System successfully integrates cutting-edge technologies into the farming process, achieving autonomous fruit harvesting and secure remote access, monitoring, and maintenance. This system reduces the need for human labor in order to perform this difficult but highly crucial task.

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References

- [1] H. Kulhandjian, Y. Yang and N. Amely, "Design and Implementation of a Smart Agricultural Robot buiIDOG (SARDOG)," in Proc. of IEEE International Conference on Computing, Networking and Communications (ICNC), Big Island, Hawaii, Feb. 2024.
- [2] H. Kulhandjian, N. Amely, M. Kulhandjian, "AI-based Fruit Harvesting using a Robotic Arm," in Proc. of 16th Intern. Conference on Precision Agriculture, Manhattan, KS, July. 2024.
- [3] H. Kulhandjian, D. Rocha, B. Bennett, N. Amely, M. Kulhandjian, "AI-based Precision Weed Detection and Elimination," in Proc. of 16th International Conference on Precision Agriculture, Manhattan, Kansas, July. 2024.
- [4] H. Kulhandjian, "SARDOG Demo Fresno State," YouTube, May 2023. <https://www.youtube.com/watch?v=xH7gShrxuqI>

