AI-based Pollinator using XY-Core Robot

F3 FARMS FOOD FUTURE

Electrical & Computer Engineering

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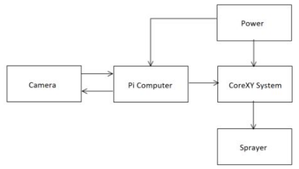
Abstract

The declining populations of natural pollinators, exacerbated by pesticides and intensive farming, pose significant ecological challenges. To address this, we are developing an AI-based pollinator using a CoreXY system to enhance agricultural pollination. This innovative approach leverages deep learning and robotics to automate pollination, increasing crop yields and quality while mitigating the adverse effects of pesticides and climate change. Our solution integrates a flower detection and pollination system into the existing CoreXY weed detection framework. Equipped with a pollen sprayer, an integrated camera, and a trained YOLOv8 deep learning model, the system identifies flowers and pollinates them without physical contact, ensuring plant health. Our AI-based pollinator offers a sustainable, advanced solution to the problem of declining natural pollinators.

Objectives/Applications

The main objective of the AI-based Pollinator using the CoreXY system is to allow the SARDOG robot to pollinate various flowers (like the one pictured on the right) that can integrate a configuration of stepper drivers and motors to the CoreXY system. This will be accomplished by training a flower detection computer vision model, creating software to drive the system, and utilizing the CoreXY frame.

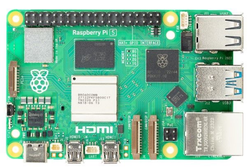


Generic System Block Diagram

Cucumber Flower | Strawberry Flower | Cherry Tomato Flower

Dataset Flower Examples

Components



Raspberry Pi 5 with Broadcom BCM2712 Quad-Core Arm Cortex A76 Processor

DM542 Microstep Drivers

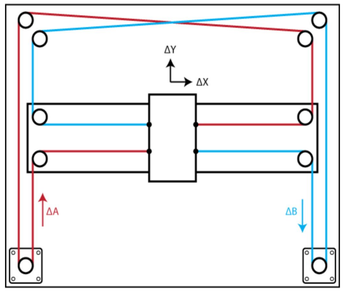
Nema 17 Stepper Motors

Electric Pollinator gun

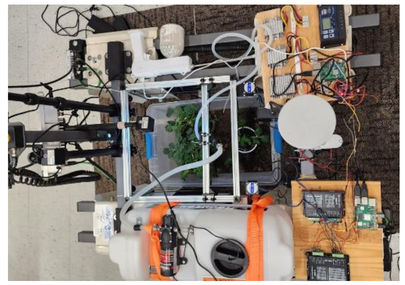
ELP Sony USB Camera

Various V-slot Aluminum Extrusions and Components

Hardware Design



CoreXY Belt Configuration and Kinematic Equations

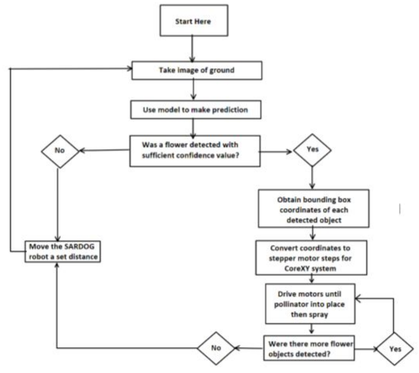


Full SARDOG Setup

We utilized the CoreXY design, as depicted above, to create an efficient Cartesian movement system capable of positioning the pollen sprayer through a coordinate system utilizing stepper motors. Raspberry Pi GPIO controlled signals as it was linked to the motors and Drivers on the CoreXY frame.

Software Design

The Raspberry Pi 5 computer was programmed with a CoreXY driver (using python.) The general behavior of this program is depicted in the flowchart on the right. This driver utilizes a trained YOLOv8 computer vision model to detect flowers, determine their coordinates, and drive the stepper motors until the sprayer is moved into place.

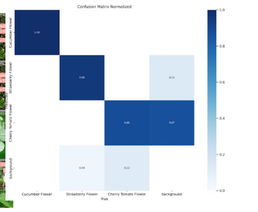


System Behavior Flowchart

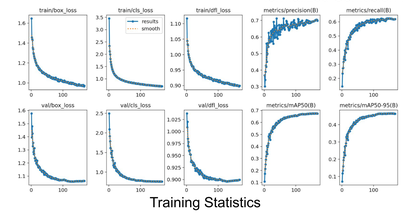
Training Results

The presented results illustrate the performance metrics of the trained deep learning model over the course of its training. At 197 epochs (the end of each graph), the model demonstrates convergence into a stable state for the provided flower data. The training algorithm determined that the model was most stable at epoch 172. This model performs well by all metrics, achieving a mAP50 accuracy rating of approximately 94%. This level of performance is ideal for the flower pollination system, allowing for accurate and precise detection and pollination of flowers.

Training Validation Example



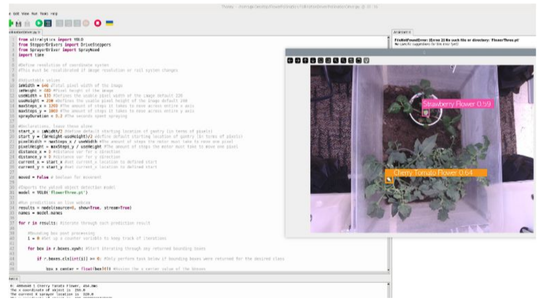
Normalized Confusion Matrix



Training Statistics

Experimental Setup and Testing

The CoreXY pollination frame is centrally mounted on the robot. At the bottom right, the two stepper drivers and the Raspberry Pi 5 computer are securely fastened to the wooden board. The camera is positioned to look straight down beneath the robot, providing a clear view of the flowers below. Additionally, a box containing soil and flowers is placed directly under the pollination system to test its performance on real flowers.



Working System Close Up and CoreXY Driver Program Performing Predictions

Experimental Results

Results showed the flower detection model operated at taking inferences every few hundred milliseconds. When detecting the flower the CoreXY driver retrieves the box coordinate, positioned the sprayer nozzle over each flower activating the electric pollinator. This shows a successful implementation of the flower detection and pollination.

Conclusion

Using a CoreXY kinematic system and computer vision software we successfully developed a unique AI-based pollinator and elimination system. Originally designed to be a linear actuator, the elimination system saw many improvements allowing it to become the sophisticated and efficient machine it is now.

Acknowledgements

Support and funding for this effort were partly provided by the U.S. Department of Education, Title V Promoting Postbaccalaureate Opportunities for Hispanic Americans (Finish in Five), Project Grant P031M210039 and by the Economic Development Administration (EDA) Project Grant 077907908, Fresno-Merced Future of Food Innovation (F3) Coalition.

References

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[2] 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.

[3] H. Kulhandjian, "**SARDOG Demo Fresno State**," YouTube, May 2023. https://www.youtube.com/watch?v=xH7gShrxuqI

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