

A Low-Cost Robotic Gantry System for Multimodal Data Collection in Controlled-Environment Agriculture

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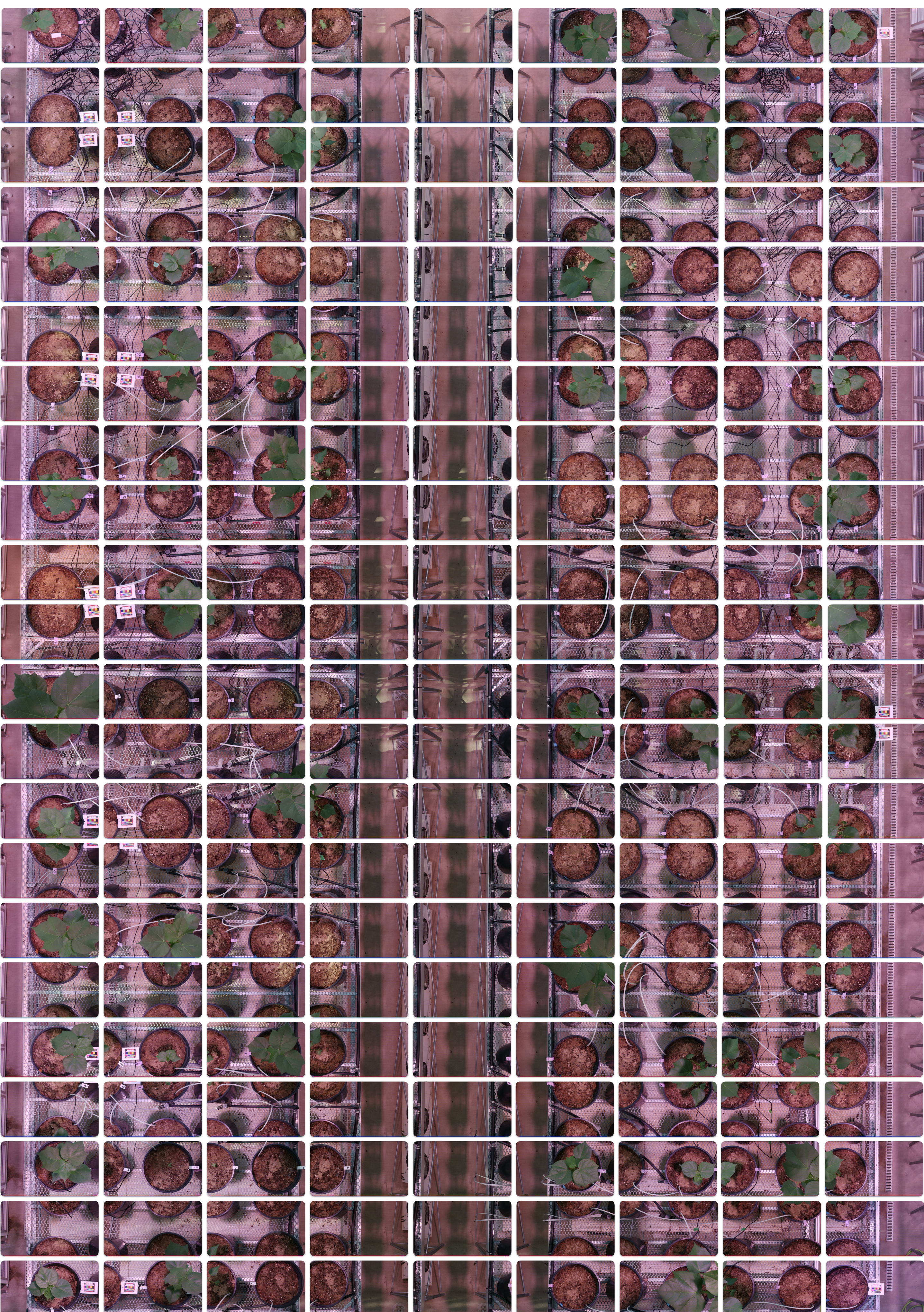
Abstract

Computer vision has shown great promise as relevant means of assessing plant health and vigor, leading to the utilization of high-throughput imaging as one of the most effective methods for monitoring plant growth, detecting stress and disease. However, imaging systems are often incredibly expensive while the software used for control and analysis are not open source.

We present a low-cost, open-source robotic gantry system (3 × 4 m) designed for high-throughput data collection in greenhouse environments. The gantry carries a flexible suite of sensors—including infrared, RGB, and stereo-depth cameras—mounted on a manually height-adjustable platform. A Raspberry Pi computer controls gantry motion and manages data acquisition. Structural rigidity is provided by V-groove 2 × 2 inch aluminum extrusions, while stepper-motor-driven belts enable smooth two-axis movement across the full range of the frame. All mechanical components, control electronics, Wi-Fi connectivity, and software were developed in-house with careful attention to cost, resulting in a total system cost under \$2,000. This affordable and adaptable platform lowers the barrier to scalable data collection for controlled-environment agriculture, enabling farmers and researchers to deploy advanced sensing technologies at a fraction of the typical cost.

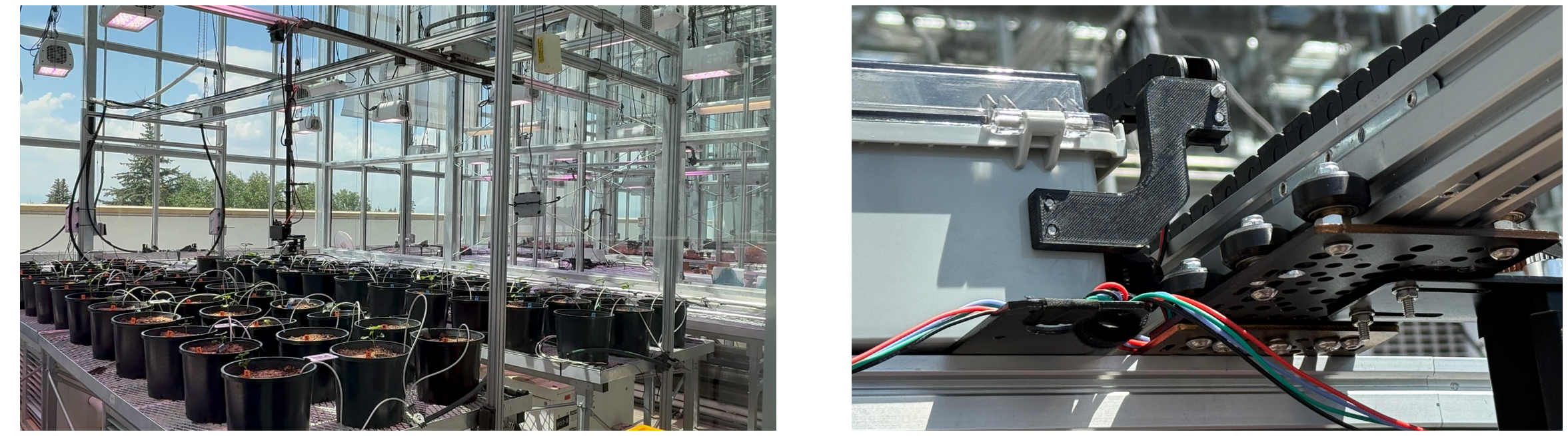
Results

Data collected for cotton plant growth, x4 times a day for ~1 month.

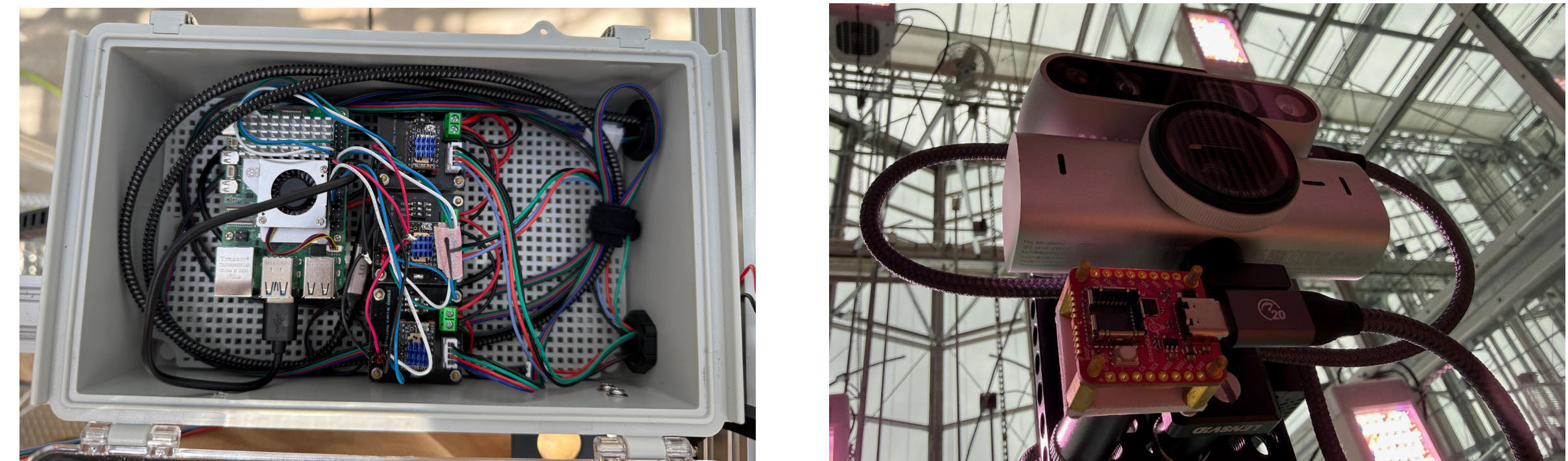


System Design

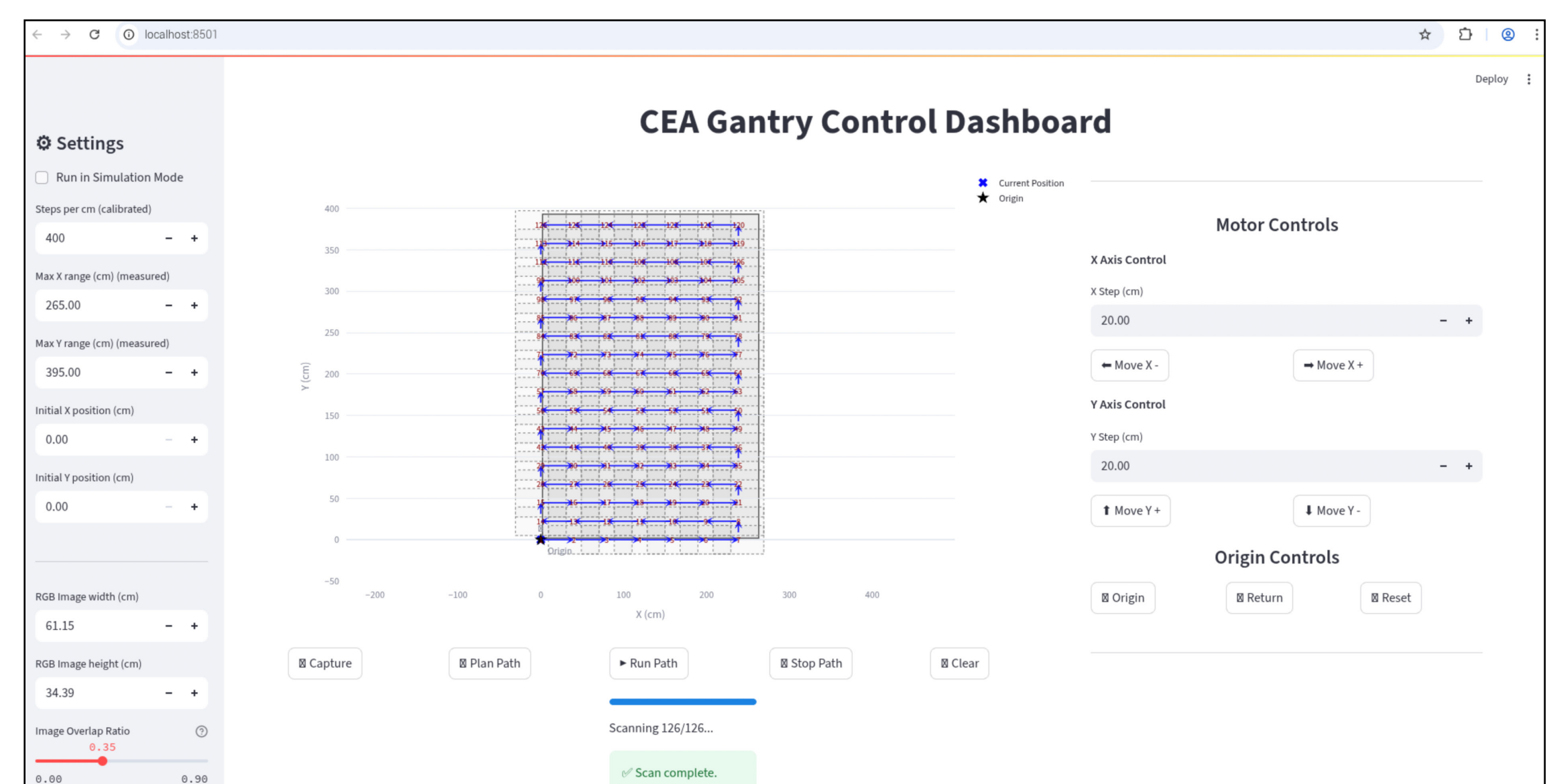
Mechanical: Belt-driven v-groove Al Extrusion



Electrical: Stepper-motor & Raspberry Pi controls
Payload: RGB, Stereo Depth & IR Cameras

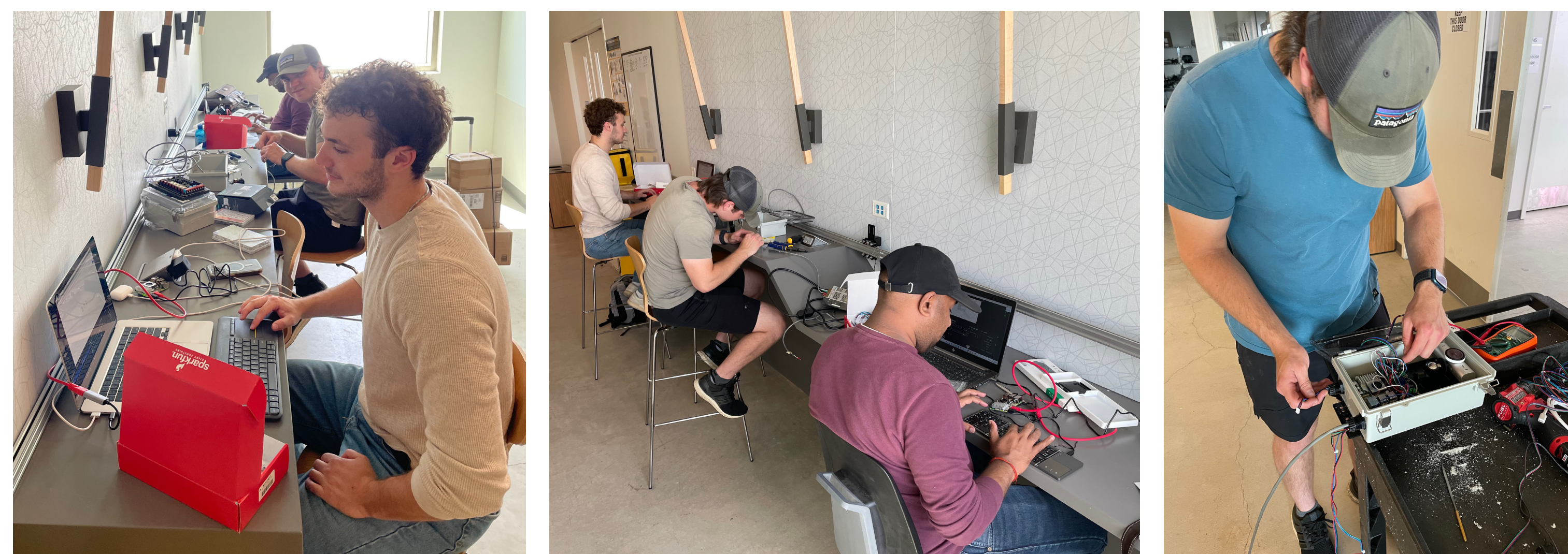


Software: Custom python and streamlit dashboard



Work in Progress

- Solve imaging parallax effects when plants grow tall.
- Combine IR, Depth Imaging with RGB data.
- Work out TMC2209 sensorless homing when returning back to home.
- Instead of image stitching, make individual plant photos by doing computer-vision-based object detection for centering & adjusting motor positions.
- Real-time inference of plant growth state.
- Automated image scaling & color calibration.
- Error detection during automated gantry movements.
- Package entire design & code base for open source publication.



We had fun!!!

Acknowledgement

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