VF-PLUME

Vertical Farming Plant Localizing UAV with Mass Estimation

PURDUE UNIVERSITY

UAS Research and Test Facility

AIR FORCE RESEARCH LABORATORY

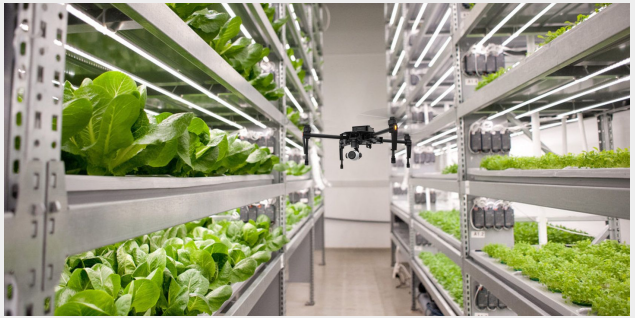
Unmanned Aerial Systems (VIP)

VIP Vertically Integrated Projects

Contents

Introduction

- Growing population, especially in urban areas, requires more efficient farming
- Vertical Farming is a growing industry in agriculture
- Great control over environmental factors
    - Increased crop survival rate
    - Increased yield per acre
- Becoming more popular globally



(Eden Green Technology, 2023), (iFarm, 2023)

The Problem: How Do We Track Growth of Plants?

- Wish to monitor environment and plants to ensure high yields
- Previous monitoring techniques
  - Human observation
  - Stationary sensors/cameras
- Human monitoring requires time and effort
- Monitoring system requires capital and maintenance

(Global Crop Technology)

The Solution

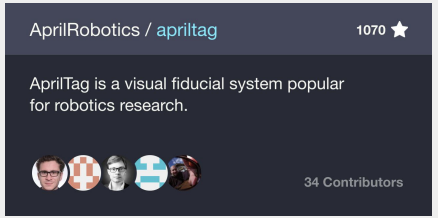
"VF-Plume"

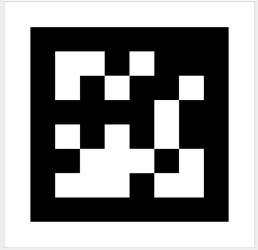
1. Drone Localization
2. Point Cloud Segmentation
3. Plant Mass Estimation
4. Environmental Data Collection

VF-Plume

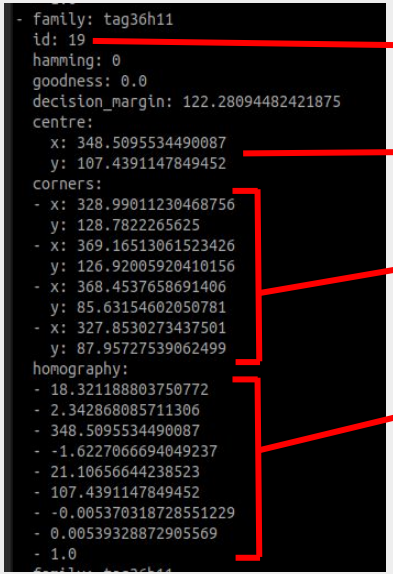
Drone Localization: April Tags

- April Tags - provide 2D-plane reference in 3D space
- From recorded rosbag of drone's camera capture and motion, AprilTags locations (x,y) were noted
- Visualized and plotted dense areas of AprilTags as Pointcloud using Open3D (Data & Analysis)





36h11 family AprilTag



Unique ID for each Apriltag in family

Coordinates of Apriltag center

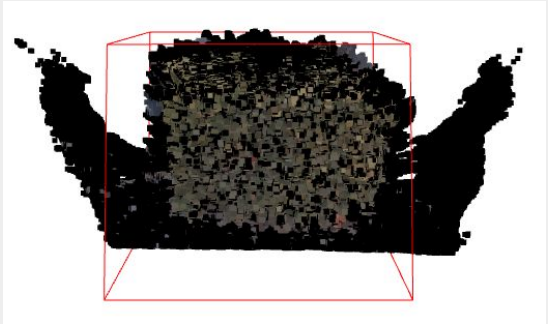
Coordinates of Apriltags' corners

Homography:

AprilTag detections output for one tag

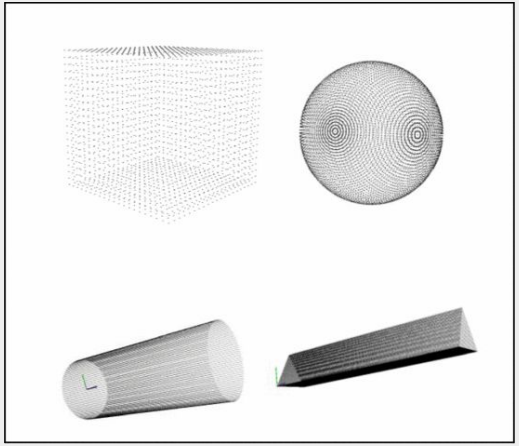
Point Cloud Segmentation

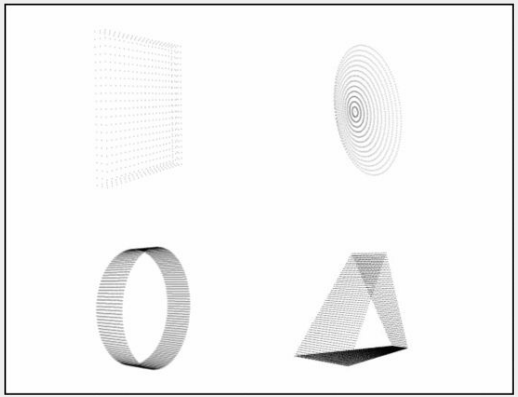
1. Filter camera color matrix for green colors
2. Create histogram for green data points in x, y, and z direction
3. Find space that does not contain lettuce by defining upper and lower bounds of histogram value
4. Use empty space to create bounding box around volume that contains lettuce



Plant Mass Estimation

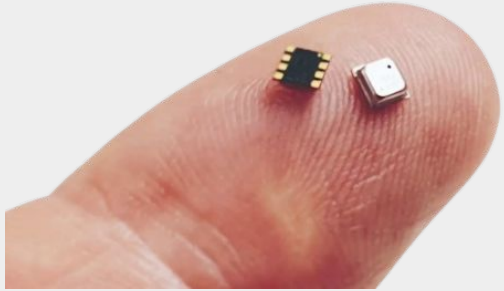
1. Segment general point cloud to individual plants
2. Separate segmented point cloud into many 2D slices
3. Fit points in 2D slice to a polynomial curve
4. Integrate curve for area
5. Integrate area for volume
6. Multiply volume with density for mass estimation



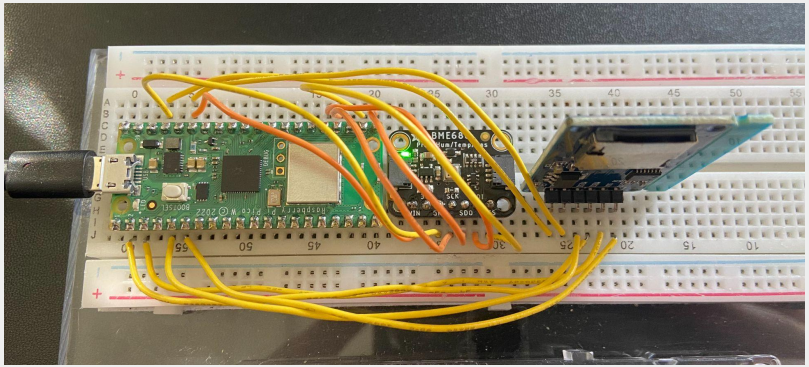


Environmental Gas Readings

- Bosch BME688
  - Temperature, Pressure, Humidity
  - Volatile Organic Compounds
  - Air Quality Index
  - Other Gasses: Carbon Monoxide, Hydrogen
- Store data for post processing
- Next steps
  - Convert to single PCB
  - System integration



Bosch BME688 Sensor

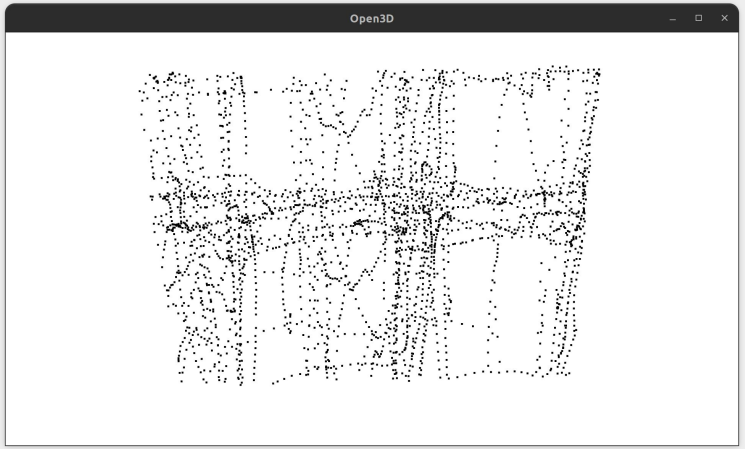


Gas Readings Circuit

Experiments, Data Analysis

- Physical data collection November 2022
  - Color camera, depth camera recordings
  - Actual April tag location
- Post processing of data
  - Open3D - Position and localization visualization
  - Masking to help with image segmentation
  - Mass estimation algorithm

Vertical Farm Test Setup



Pointcloud of Apriltags throughout flight

Future Work

Testing & Verification of Algorithms

Vehicle Robustness/Automation

- Automated monitoring, return to home, wireless charging

Interactive GUI

- 3D maps of plant growth temperature, pressure, gasses throughout farm

Data Analysis/Machine Learning

- Large amounts of data including input (temperature, pressure, presence of gasses) and output (mass of plant, plant growth rate)

Journal Publication

Works Cited

Bosch. (n.d.). *BME688 Sensor on Fingertip*. Gas Sensor BME688. Retrieved April 10, 2023, from https://www.bosch-sensortec.com/products/environmental-sensors/gas-sensors/bme688/.

Eden Green Technology. (2023). *Vertical Farm*. Eden Green Technology. Retrieved April 4, 2023, from https://images.squarespace-cdn.com/content/v1/63064607eb816a4d50027fd1/1667402354713-KZHLXNAOV98WA5ELI641/blue+skies+at+a+vertical+greenhouse+in+texas+-+vertical+farming+of+hydroponic+produce+at+eden+green+technology.jpg?format=1500w.

Global Crop Technology. (n.d.). *Man on lift monitoring plants in vertical farm*. Vertical Farming Technology. Retrieved April 10, 2023, from https://www.globalcroptech.com/vertical-farming-technology.

W. C. Chang, C. H. Wu, Y. H. Tsai and W. Y. Chiu, "Object volume estimation based on 3d point cloud", 2017 International Automatic Control Conference (CACS), pp. 1-5, Nov 2017.

VF-PLUME

Vertical Farming Plant Localizing UAV with Mass Estimation

PURDUE UNIVERSITY

UAS Research and Test Facility

AIR FORCE RESEARCH LABORATORY

Unmanned Aerial Systems (VIP)

VIP Vertically Integrated Projects