Drone Based Mapping for Crop Health Assessment

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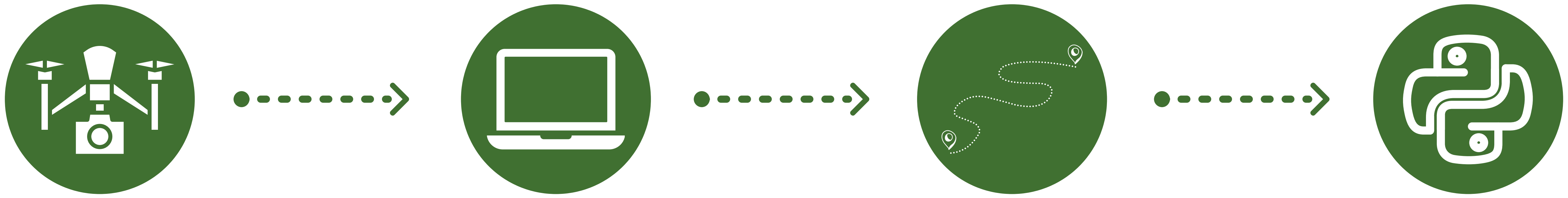
Project Objectives

- Develop an autonomous UAV platform capable of safe and reliable flights for agricultural monitoring.
- Map crop fields over an entire growth cycle using synchronized multi-sensor data (RGB, LiDAR, IMU).
- Generate accurate 3D reconstructions (point clouds and orthomosaics) to monitor crop growth dynamics.
- Design and deploy pipelines for crop health assessment through vegetation segmentation and heatmap visualization.

WORKFLOW

Drone Based Mapping for Crop Health Estimation



1- Hardware Setup

- Drone
- Realsense D455 Camera
- Livox

2 - Software Setup

- ROS1
- Ubuntu 20.04

3- SLAM Algorithm

- FASTLIO
- DLIO
- LIOSAM
- FAST LIVO2
- ....

4- Post Processing

- Plane Fitting
- Mosaic
- Ground vs Vegetation
- Weekly Growth

Hardware Setup

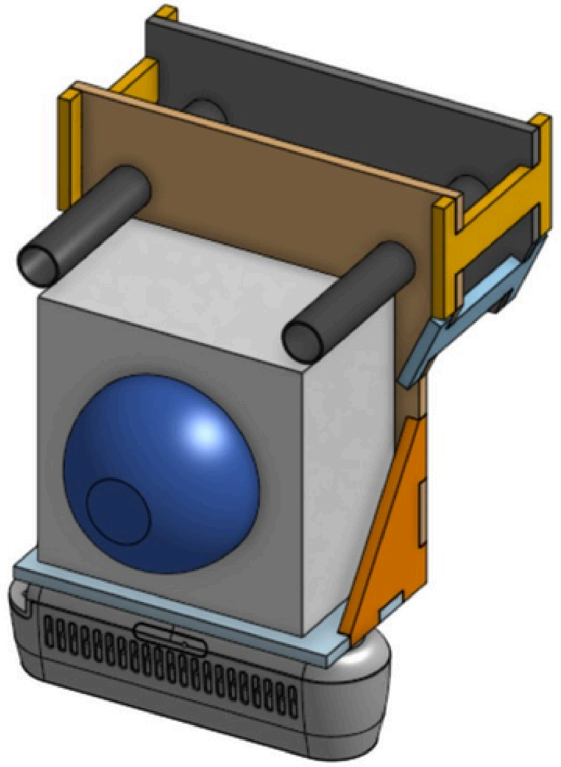
- Drone Platform (500mm, Carbon Fiber Frame)
- Pixhawk 6C flight controller with dual IMUs and onboard magnetometer
- 4S LiPo battery, ESCs, telemetry radio, GPS + compass module

- LiDAR: Livox Mid360
- 360° horizontal field of view, dense point cloud capture for mapping and crop canopy structure

- Depth Camera: Intel RealSense D455
- RGB + depth sensing for vegetation segmentation, plant counting, and fusion with LiDAR

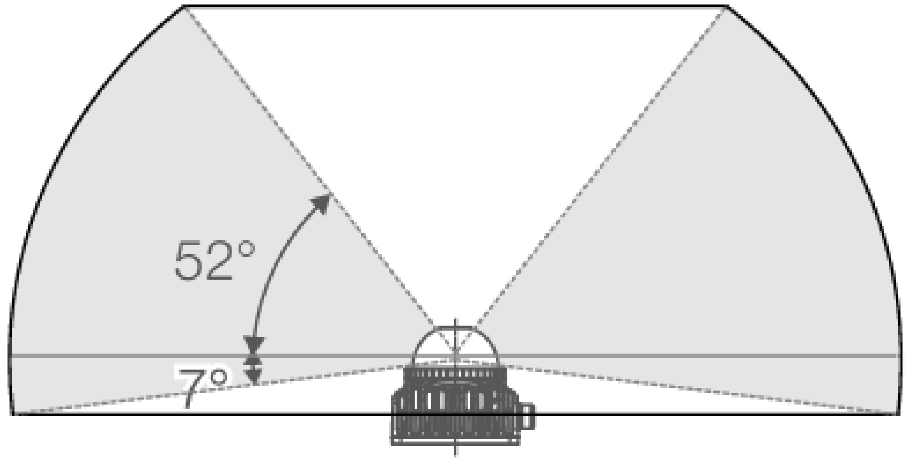
- Companion Computer: Odroid N2+
- Runs ROS stack, SLAM pipelines, sensor fusion, and crop analysis pipeline

- Supporting Systems
- Telemetry radio for ground control communication
- ESCs, motors, and power system for stable autonomous flight

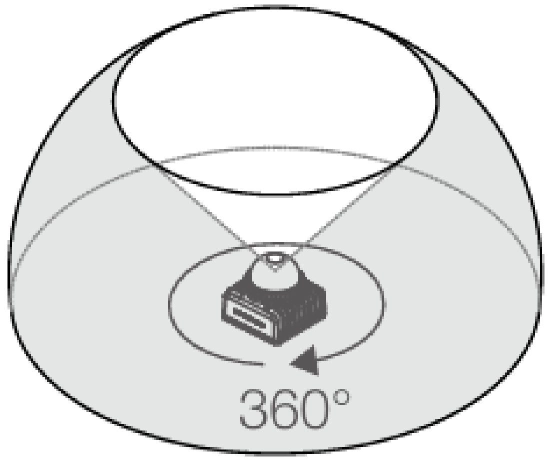


Hardware Setup

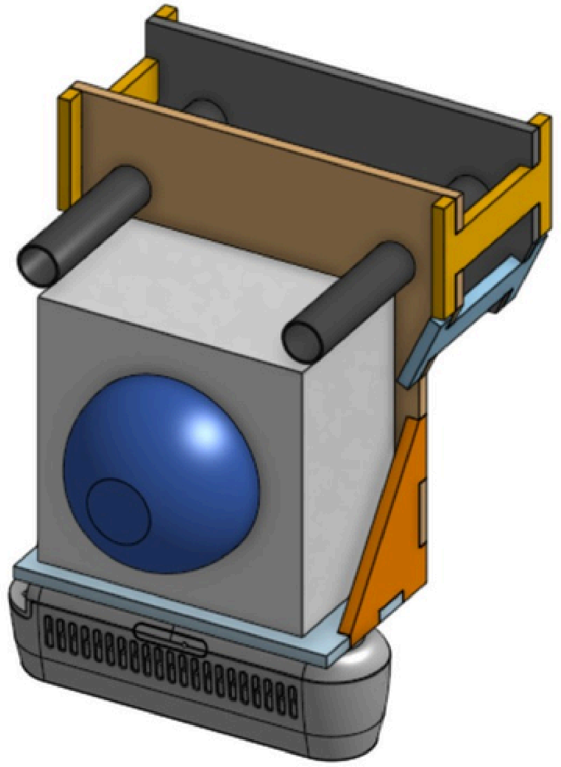
- LiDAR: Livox Mid360
- 360° horizontal field of view, dense point cloud capture for mapping and crop canopy structure
- FOV: Horizontal: 360°, Vertical: -7°~52°
- Point Rate: 200,000 points/s (first return)
- Frame Rate: 10 Hz (typical)
- Detection Range (@ 100 klx): 40 m @ 10% reflectivity, 70 m @ 80% reflectivity



Vertical



Horizontal



Software Framework

- ROS1 (Ubuntu 20.04) – Core middleware for multi-sensor integration and autonomous navigation
- SLAM & Mapping – Benchmarked FAST-LIO, FAST-LIVO, DLIO, ORB-SLAM3 for LiDAR-inertial and visual SLAM
- Point Cloud Processing – CloudCompare and Python (Open3D, NumPy) for alignment, segmentation, and analysis
- Computer Vision – OpenCV and AprilTag detection for visual localization and correction
- Data Management – rosbag logging and onboard SD card storage for flight data and experiments

SLAM

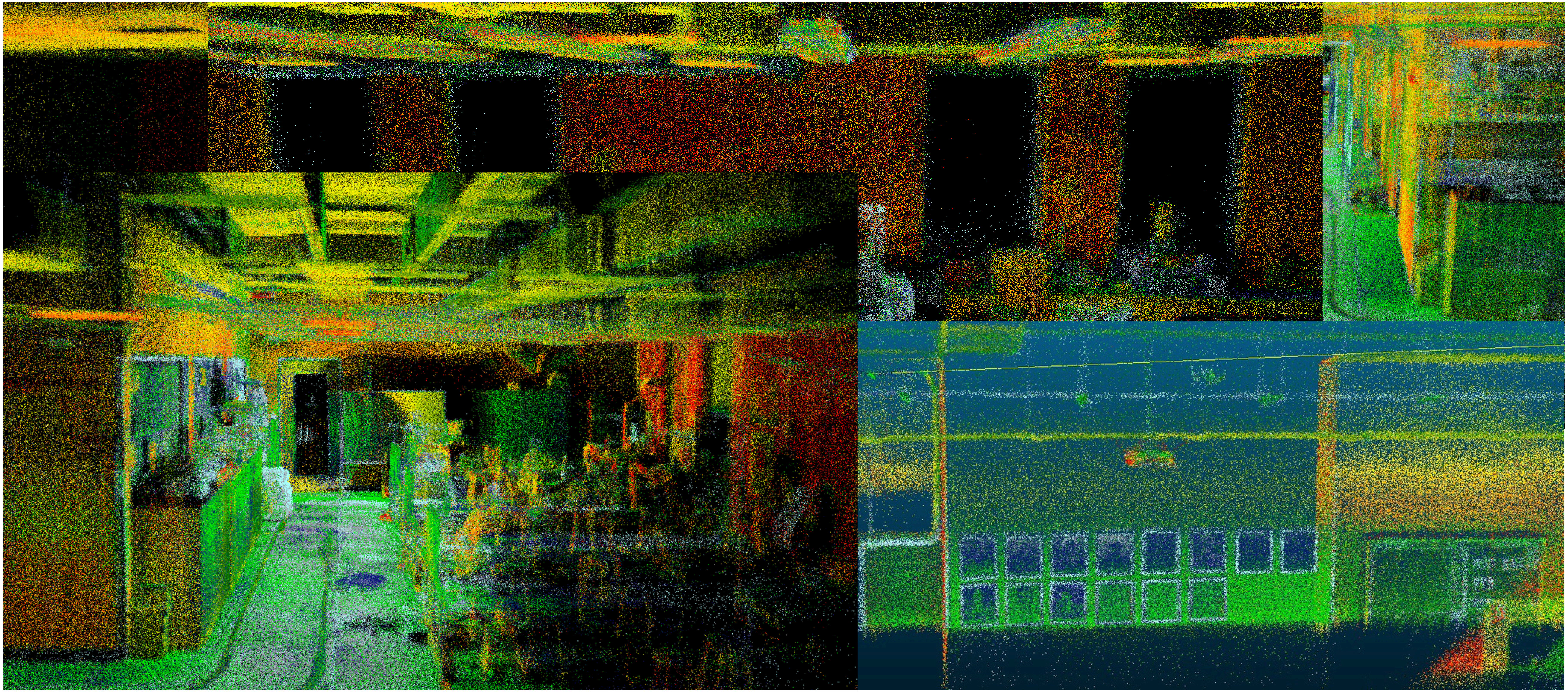
LIOSAM, DLIO, FASTLIO

- Uses LiDAR + IMU only
- Focus on geometry (point cloud structure, motion from IMU)
- Depends mostly on LiDAR features (scan matching, edges, planes)
- Robust mapping & localization, but may struggle in low-texture or repetitive crop rows
- Useful for height maps, growth tracking, structure

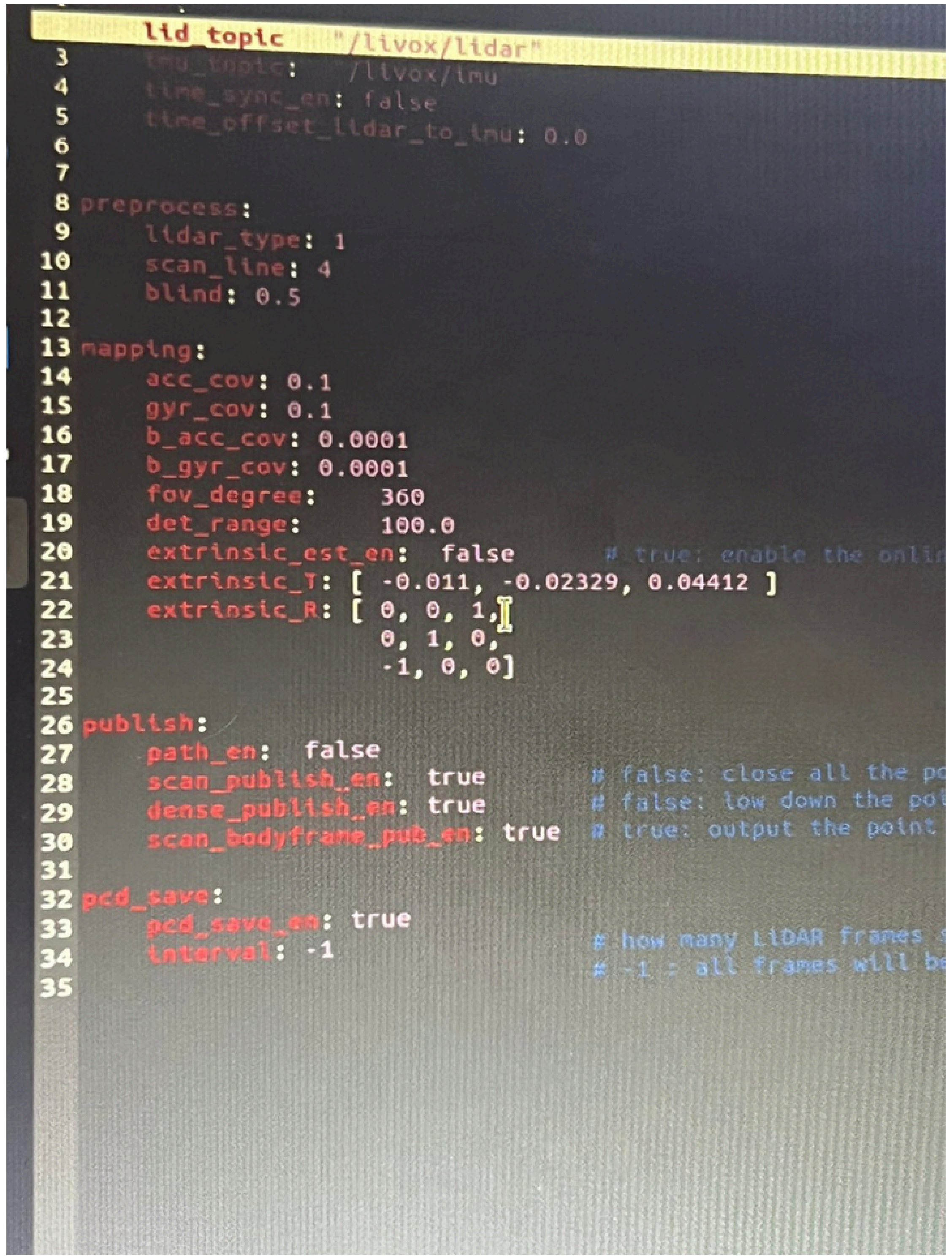
FAST LIVO2

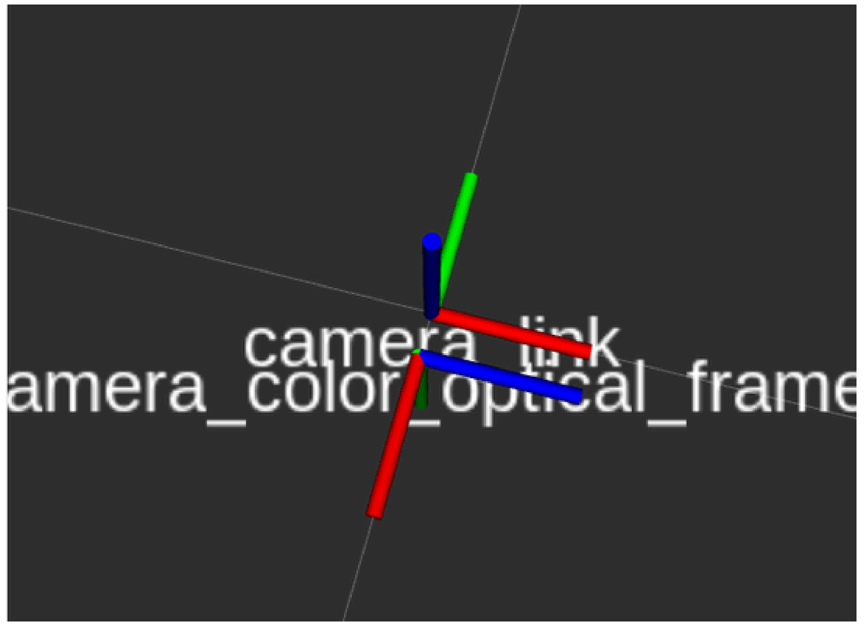
- Uses LiDAR + IMU + Camera
- Adds appearance cues (color, texture) via visual input
- Fuses LiDAR with image patches directly (no feature descriptors)
- Visual info helps disambiguate scenes → stronger in visually rich environments
- Extends to crop stress analysis and richer 3D models

Indoor Testing

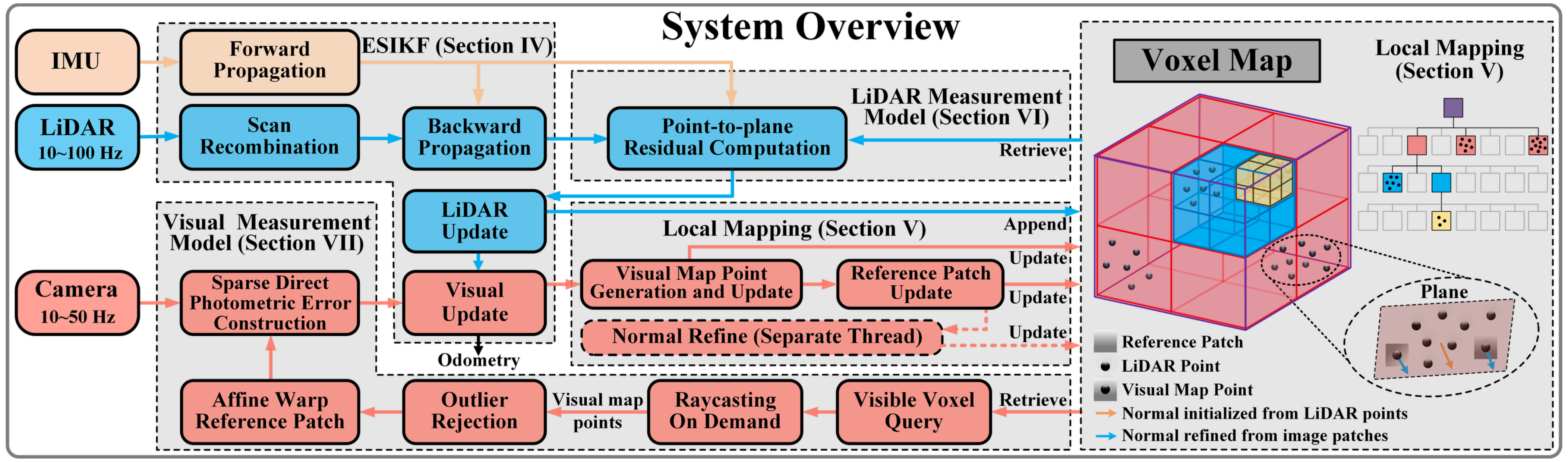


Integration of Sensors



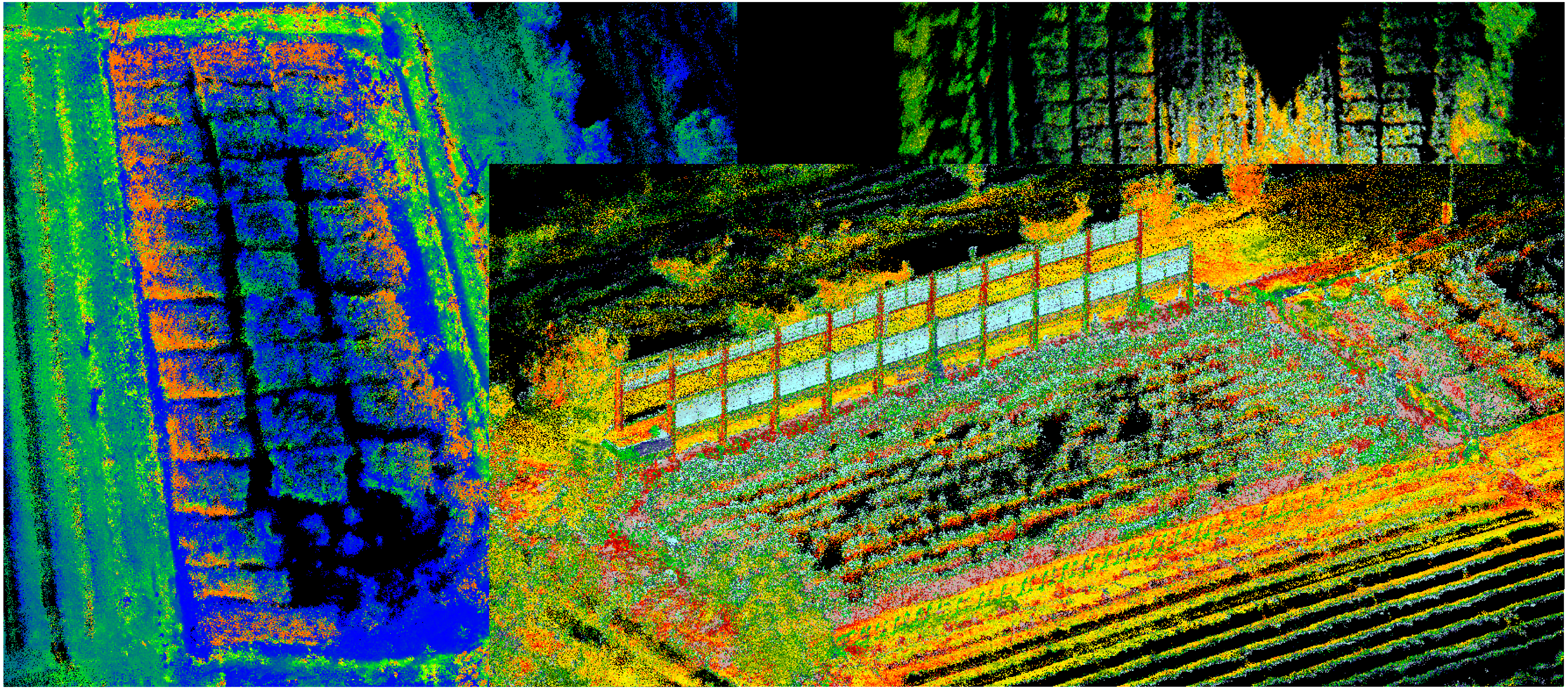


header:
  seq: 29
  stamp:
    secs: 1756892624
    nsecs: 836100578
  frame_id: "camera_color_optical_frame"
height: 720
width: 1280
distortion_model: "plumb_bob"
D: [-0.05350247770547867, 0.06272049993276596, -0.0009051245870068669, 0.0007467924151569605, -0.020540514960885048]
K: [644.1622924804688, 0.0, 656.0423583984375, 0.0, 642.6459350585938, 352.03619384765625, 0.0, 0.0, 1.0]
R: [1.0, 0.0, 0.0, 0.0, 1.0, 0.0, 0.0, 0.0, 1.0]
P: [644.1622924804688, 0.0, 656.0423583984375, 0.0, 0.0, 642.6459350585938, 352.03619384765625, 0.0, 0.0, 0.0, 1.0, 0.0]



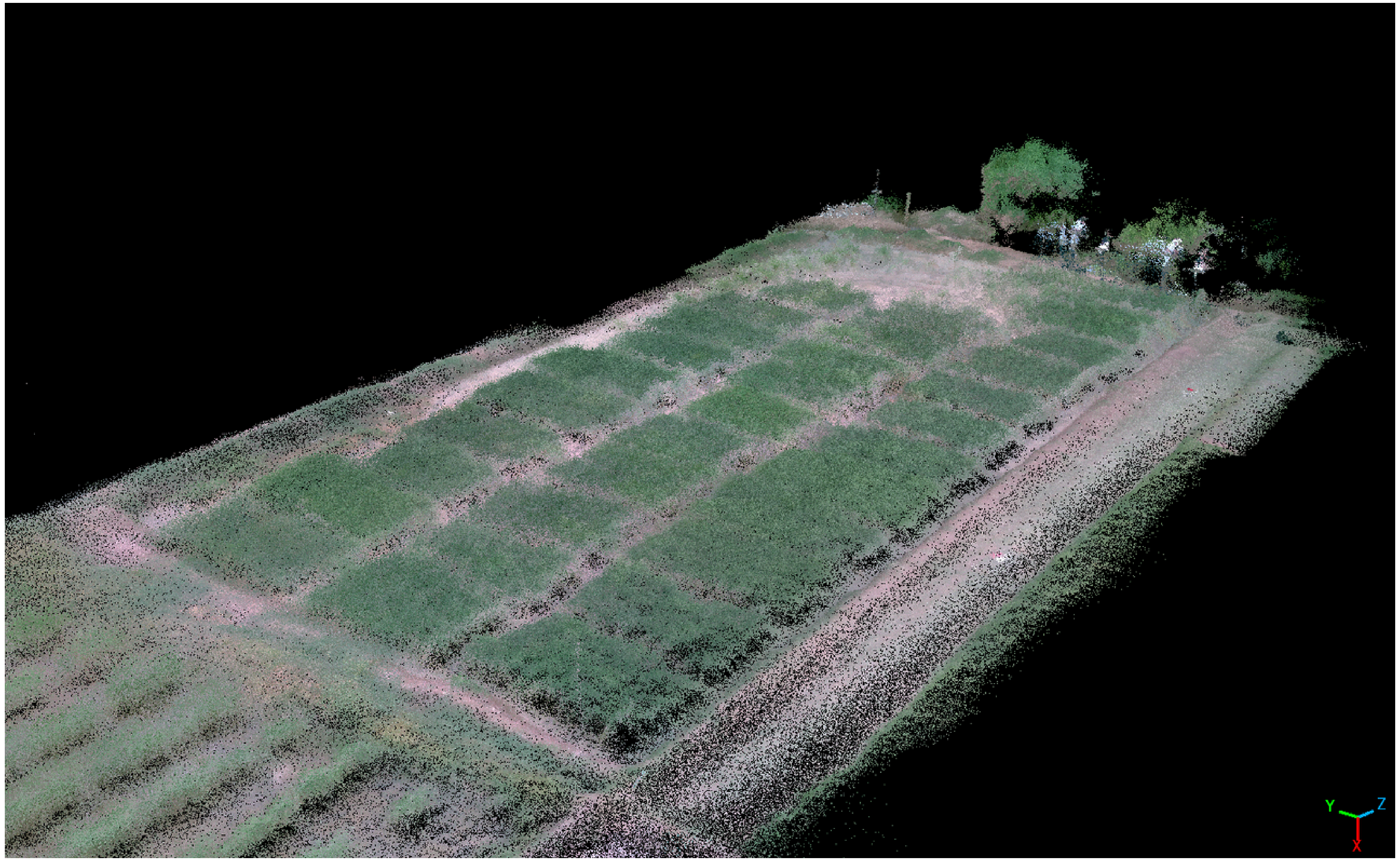
LiDAR-Inertial SLAM

Results

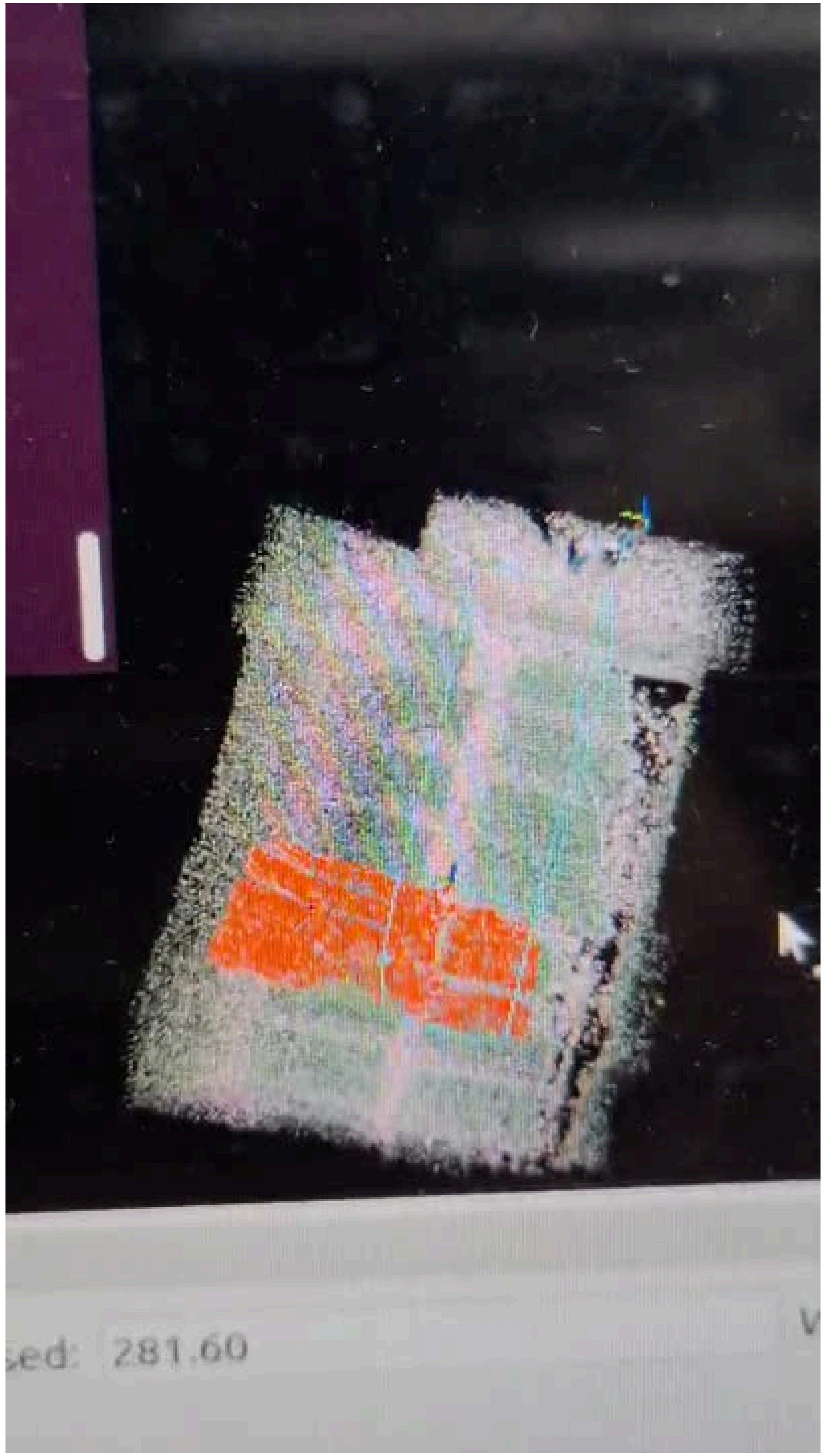


LiDAR-Inertial-Visual SLAM

Results

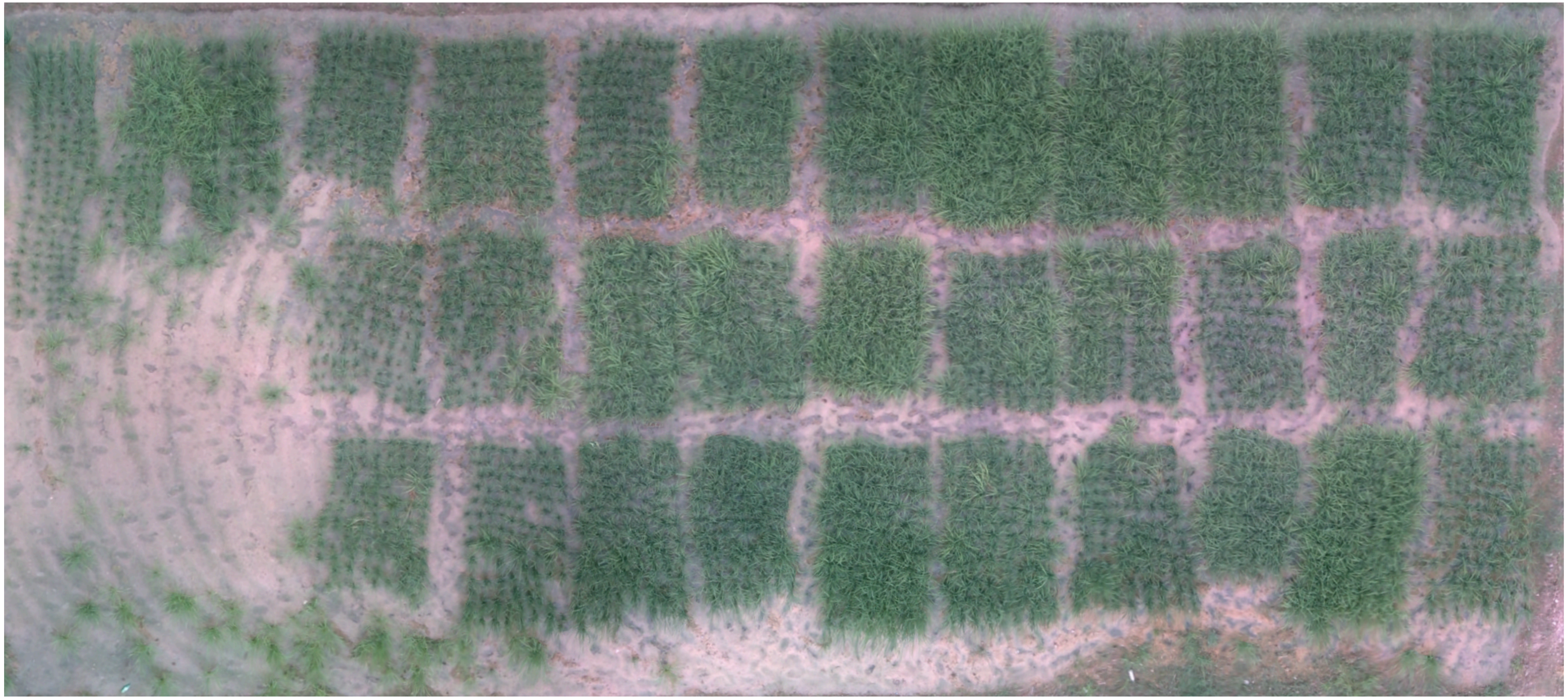


Real-time processing
FAST LIVO2

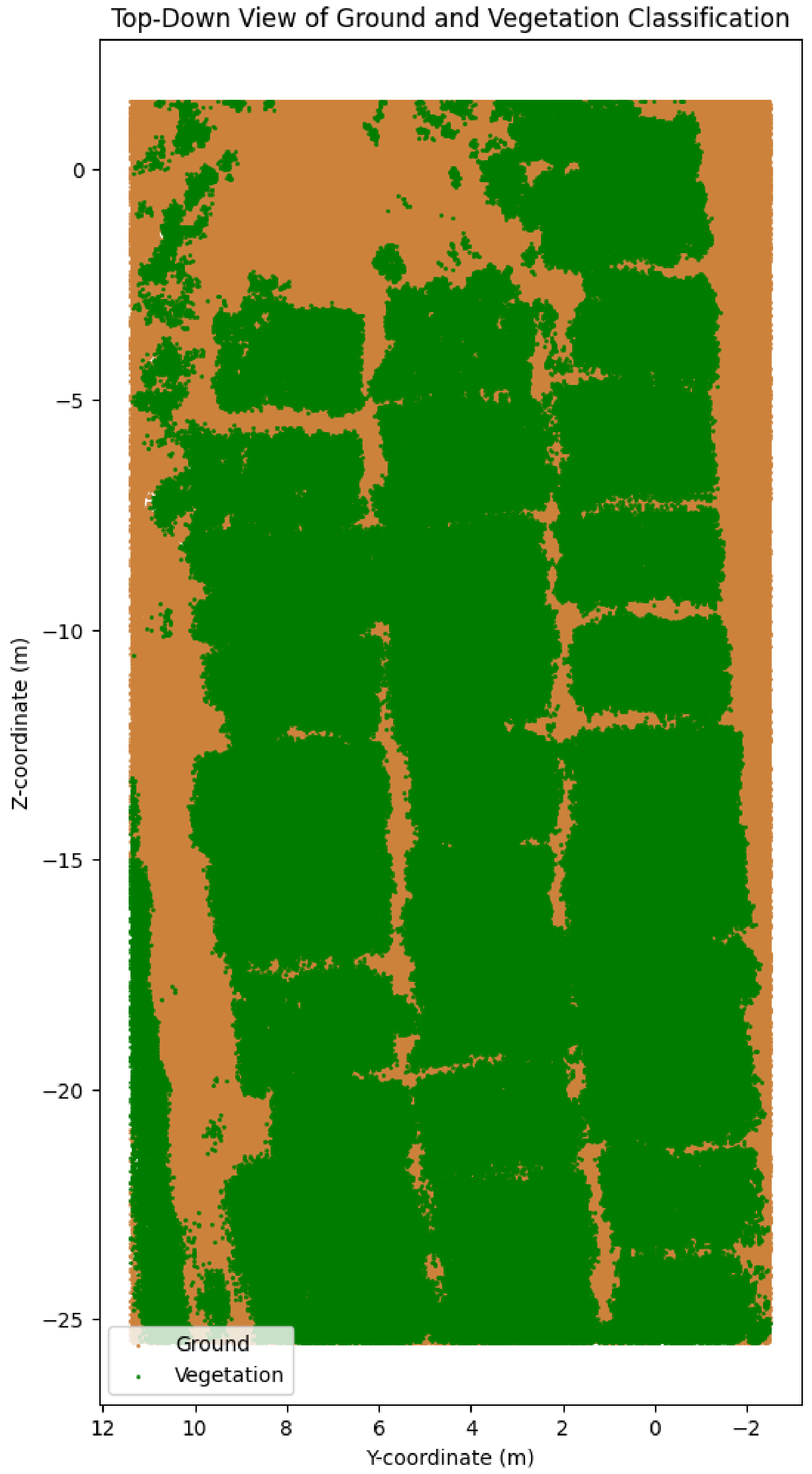


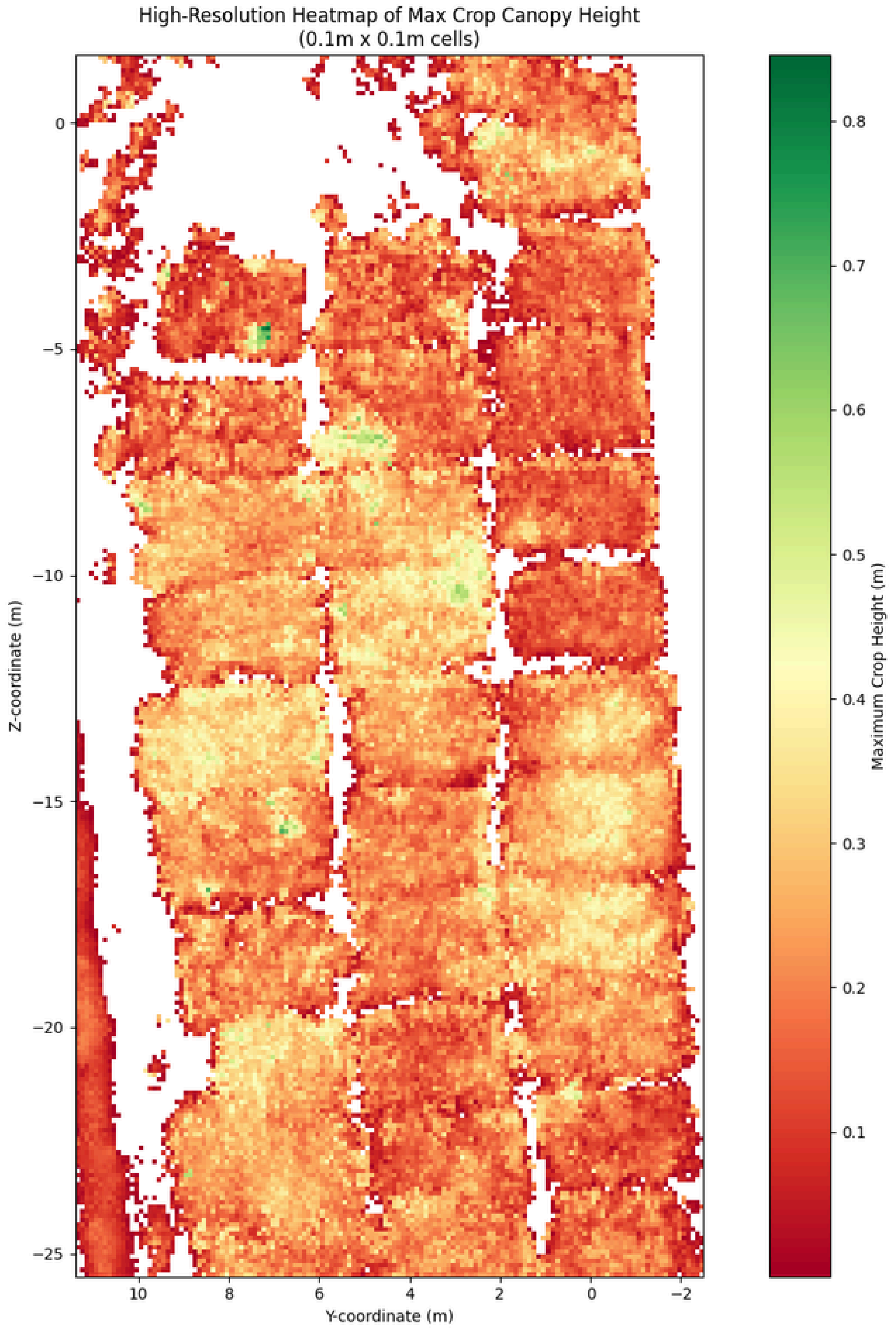
Realsense Orthomosaics

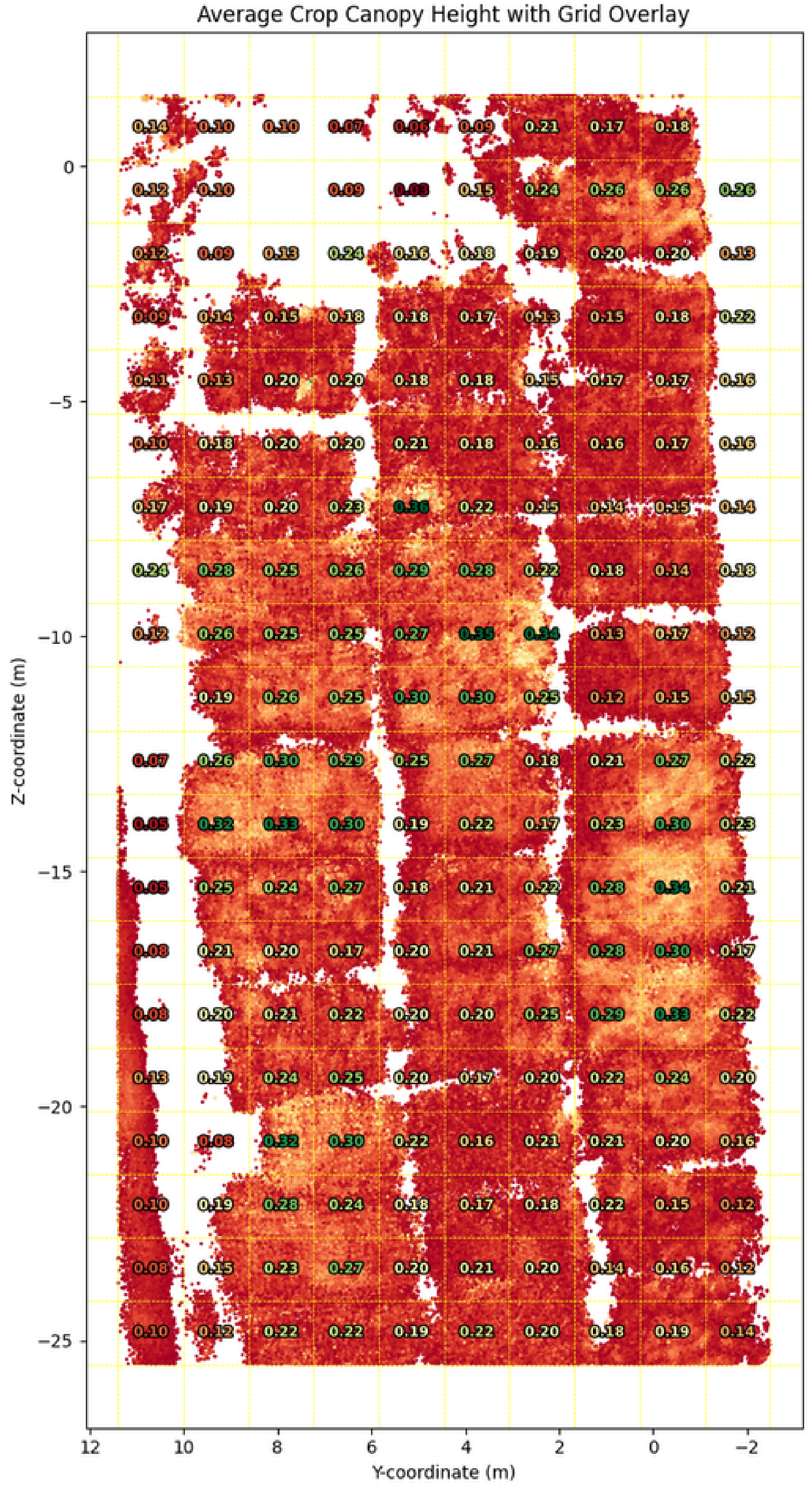
Agisoft Metashape

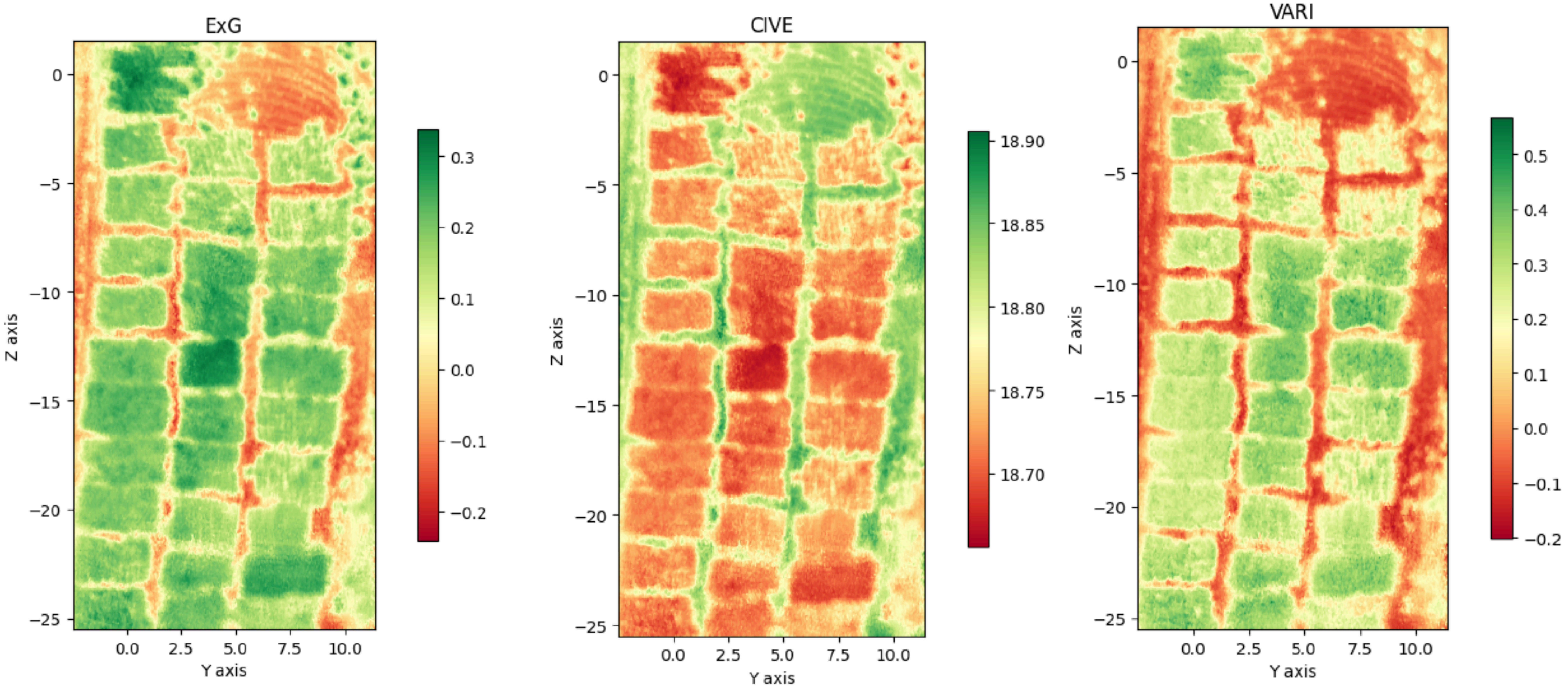


Postprocessing

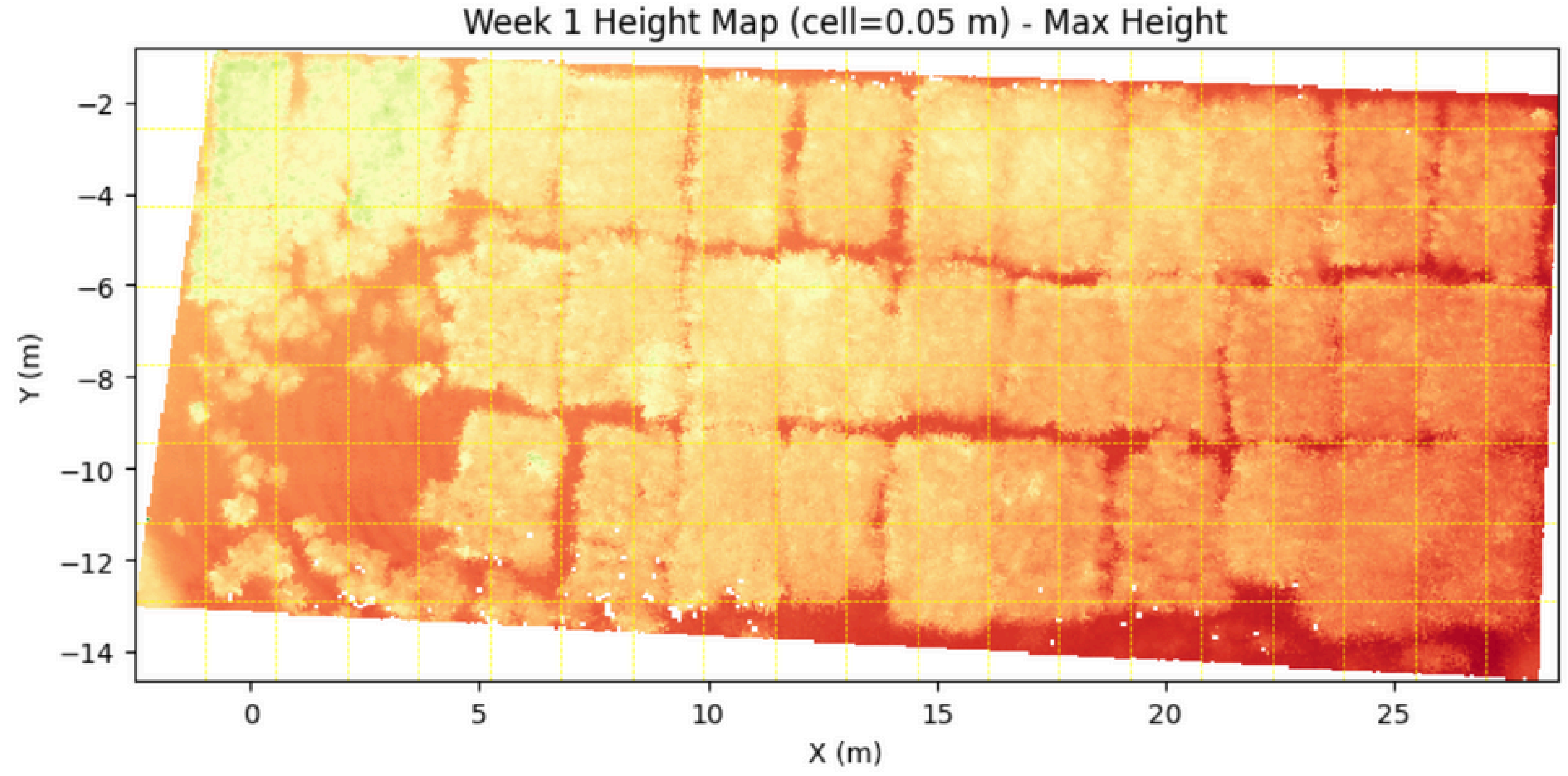


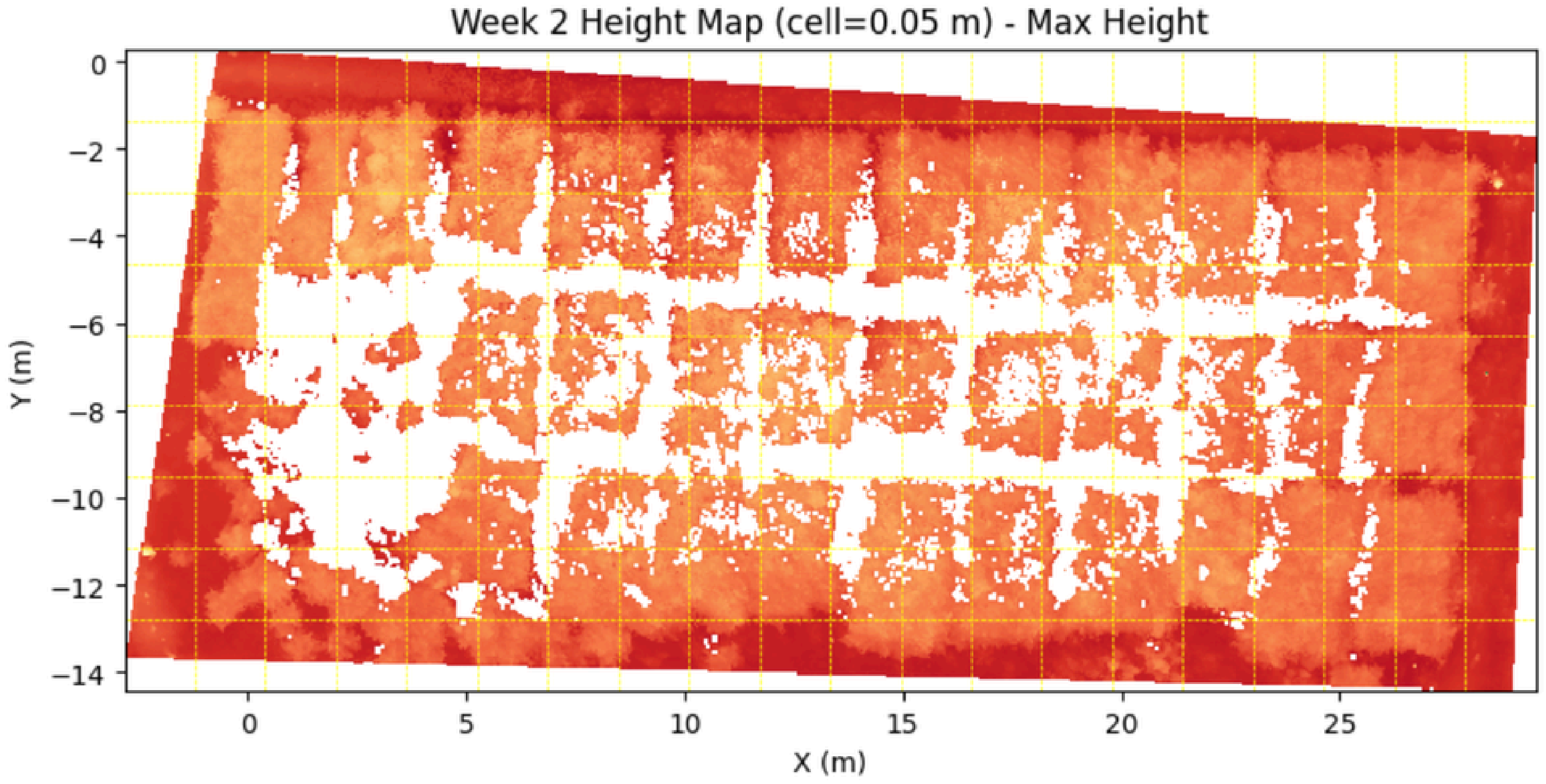


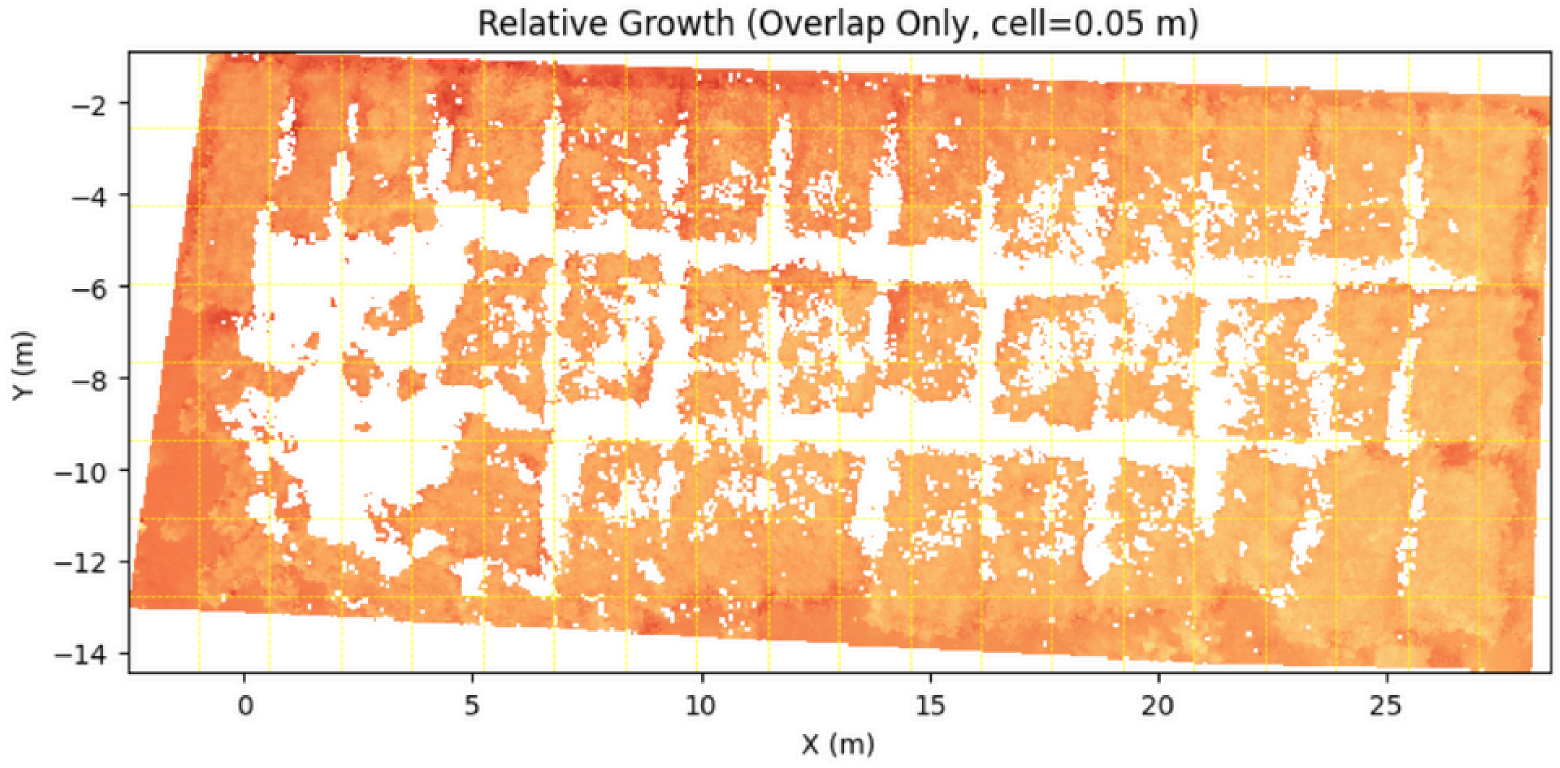




ExG
CIVE
VARI
Z axis
Y axis
0
−5
−10
−15
−20
−25
0.0
2.5
5.0
7.5
10.0
0.3
0.2
0.1
0.0
−0.1
−0.2
18.90
18.85
18.80
18.75
18.70
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2


Week 1 Height Map (cell=0.05 m) - Max Height
Y (m)
−2
−4
−6
−8
−10
−12
−14
0
5
10
15
20
25
X (m)


Week 2 Height Map (cell=0.05 m) - Max Height
Y (m)
0
−2
−4
−6
−8
−10
−12
−14
0
5
10
15
20
25
X (m)


Relative Growth (Overlap Only, cell=0.05 m)
Y (m)
−2
−4
−6
−8
−10
−12
−14
0
5
10
15
20
25
X (m)

Incident Log & Hardware Failures

Crash 1: Violent Jerks and loss of control

- SD card cracked (data loss)
- Drone arm detached

Crash 2: Hardware care, ArduPilot errors (possible GPS spoofing / magnetic interference observed recently)

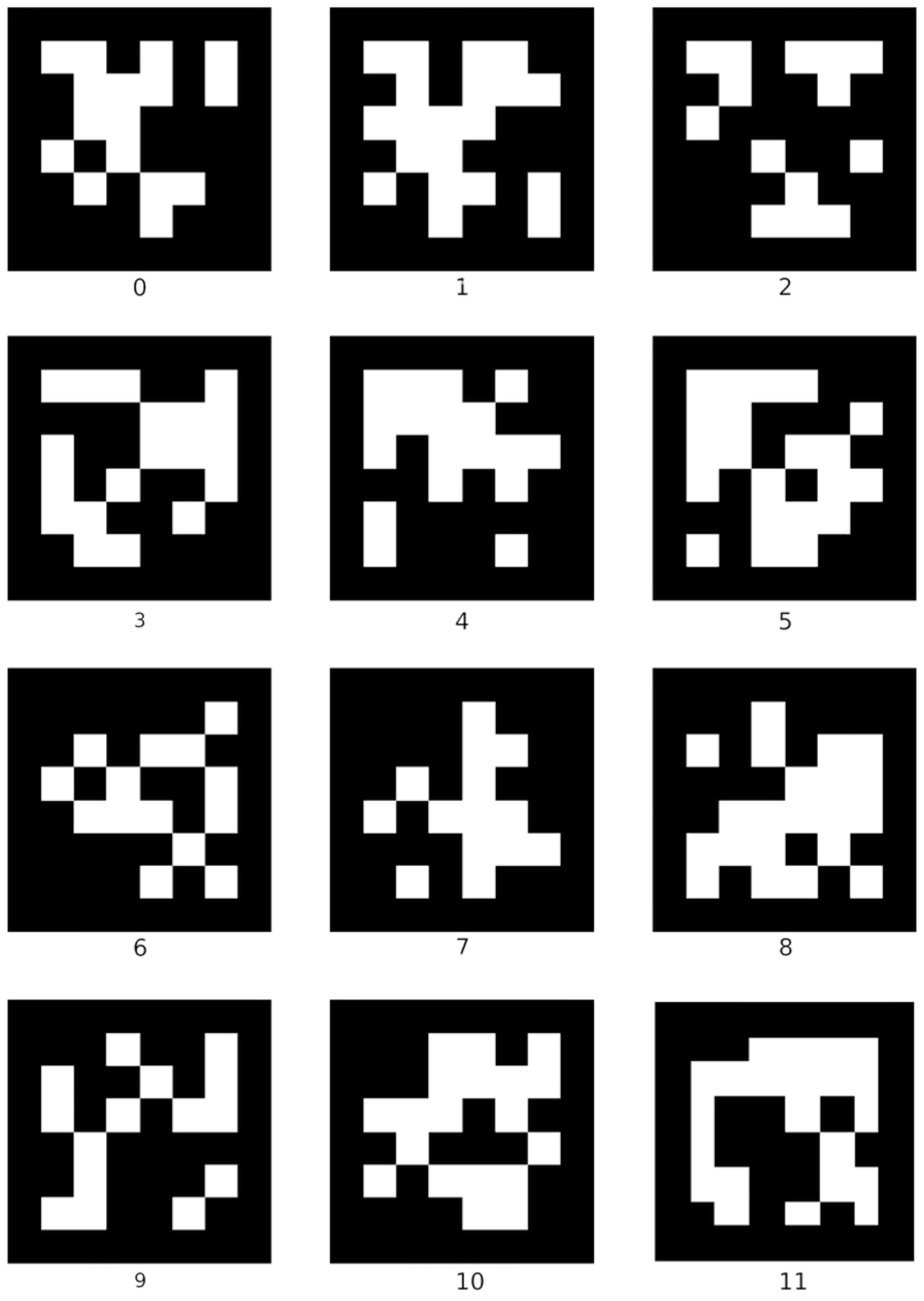
- RealSense D455 damaged
- LIVOX scratched
- Drone Frame dismantled


NOTICE
NO FOOD OR DRINK PERMITTED IN LAB
CAUTION
NO CHEMICALS IN DRAINS
USE CHEMICAL WASTE CONTAINERS
NOTICE
KEEP THIS LAB CLEAN
SPRAY PAINT

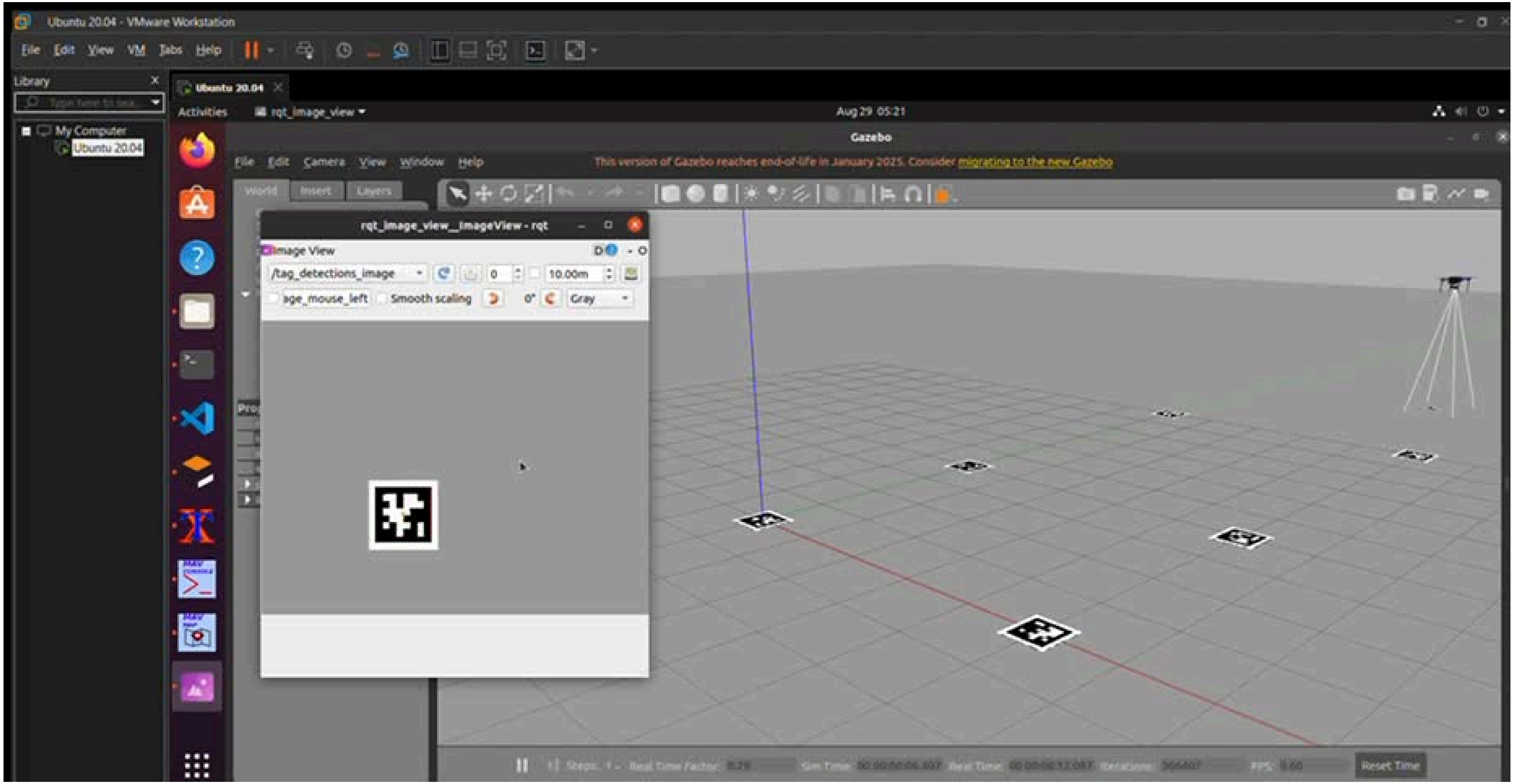
The future:

Vision-Assisted (AprilTag) Navigation and Pose Correction

The power that lies behind
/mavros/local_position/odom and /tag_detections



Simulation Demo




Thank You!