

Real Time, Onboard-only Landing Site Evaluation for Autonomous Drones

PhD Thesis Proposal

Joshua Springer

Reykjavík University

March 2022



Presentation Structure

(1) Introduction

- Problem description and motivation
- State of the Art



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 - Continuation of master thesis (tested in simulation)



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- Fiducial marker deep-dive and modifications
- Proof of concept

(3) Research Plan

- Methods
- Challenges and risk analysis



Introduction



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“Human-assisted landing”



Research Questions



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- What data do autonomous drone landing methods need?



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- How can a drone autonomously land?
- What data do autonomous drone landing methods need?
- How can those methods execute in real time onboard a drone?



State of the Art

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 - Optical flow
 - RGBD, LIDAR
- Other methods



Completed and Ongoing Projects



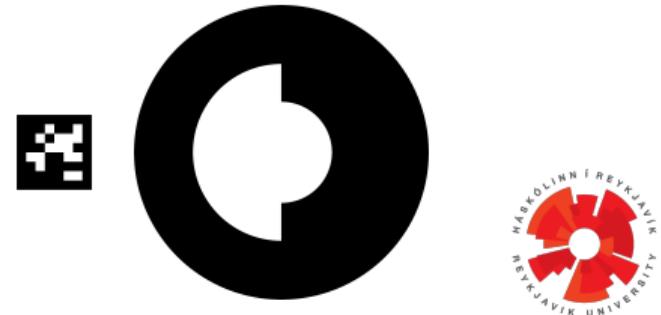
Test Hexacopters

- Two Tarot 680 hexacopters
- For real-world proof of concept of master thesis simulations.



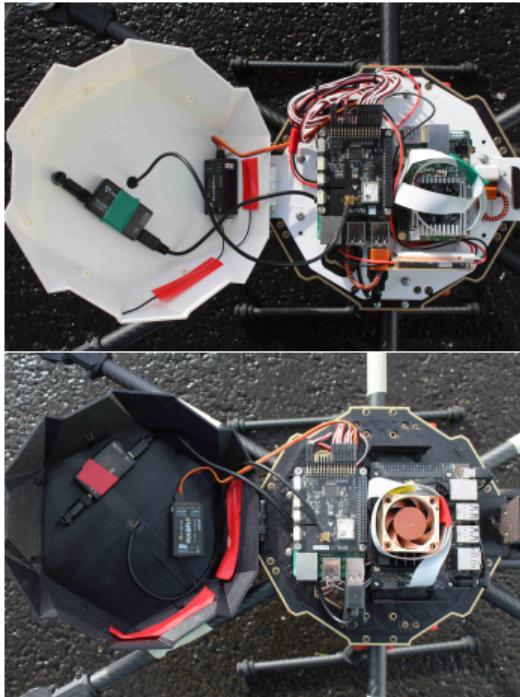
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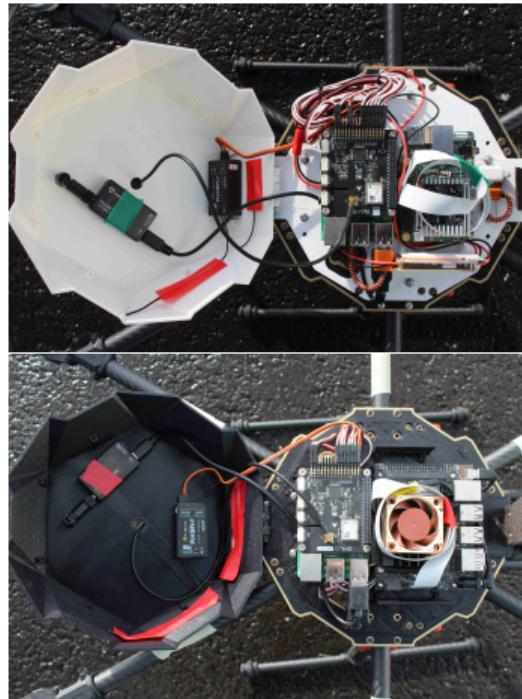
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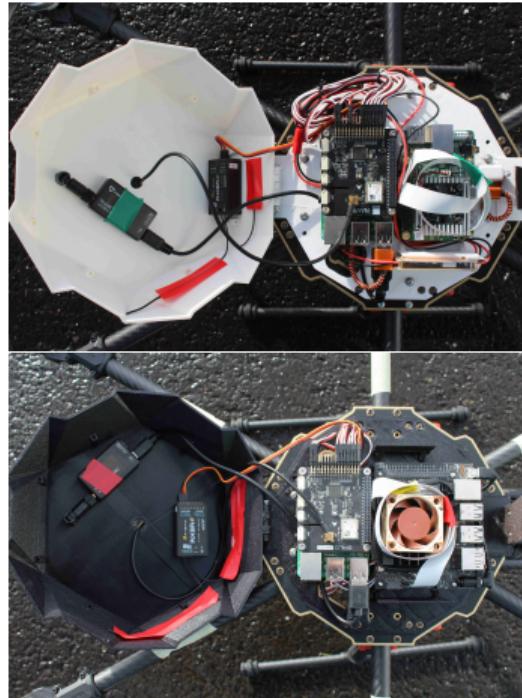
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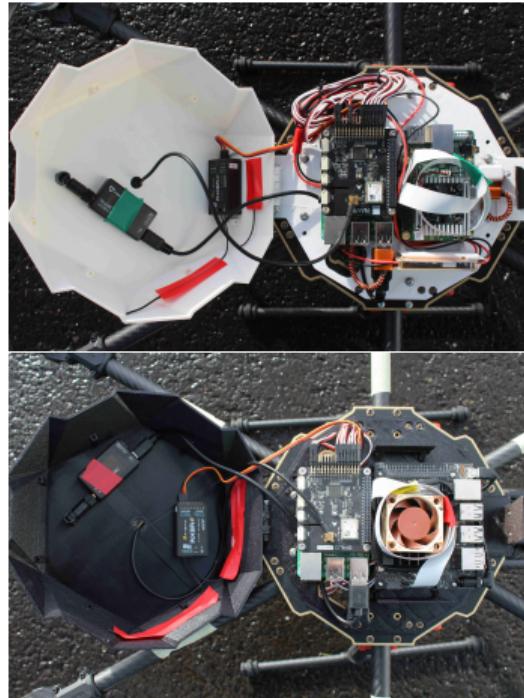
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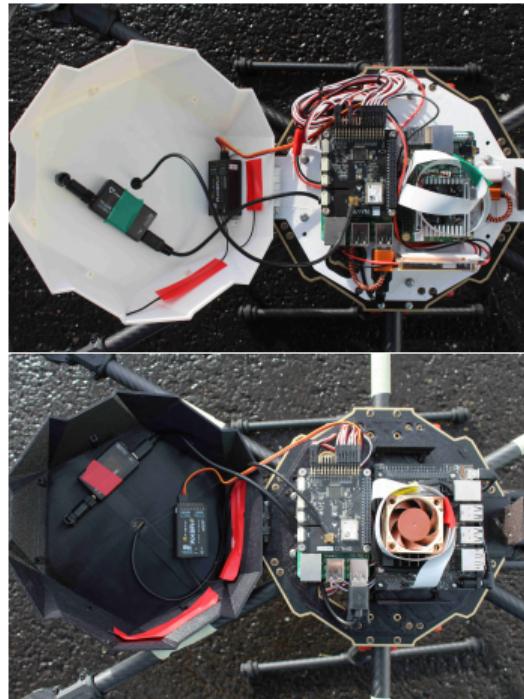
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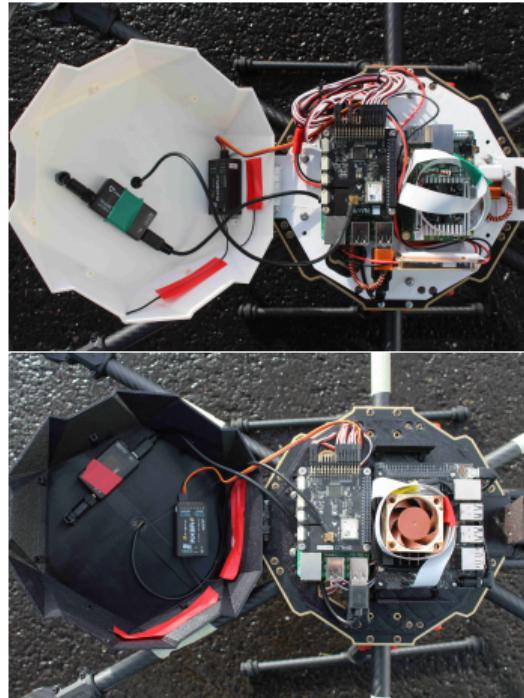
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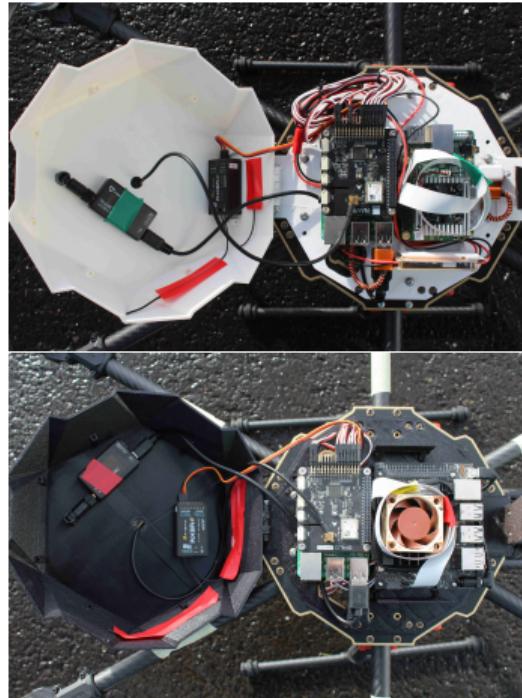
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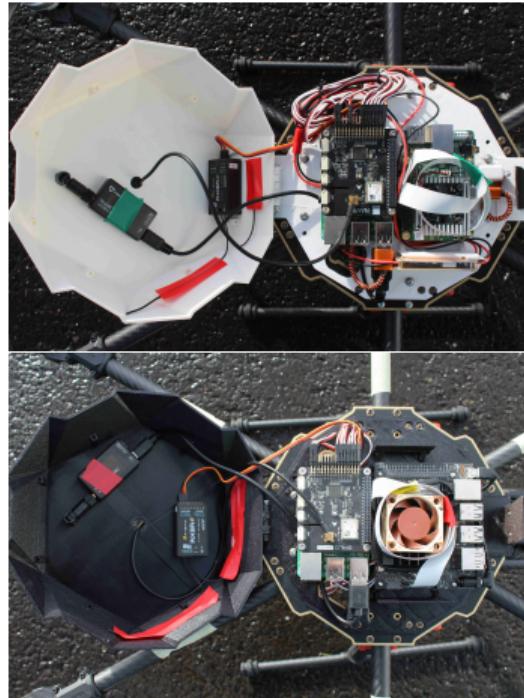
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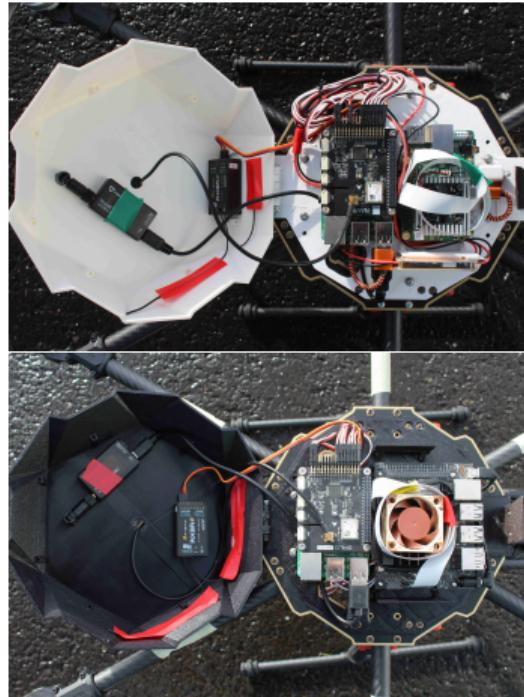
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 - ArduPilot



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 - PX4 (not technically supported)



Test Hexacopters' Performance

- Stable (manual) flight performance



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- ~20 min flying time



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- Errors during approach
 - Monocular pose estimation ambiguity



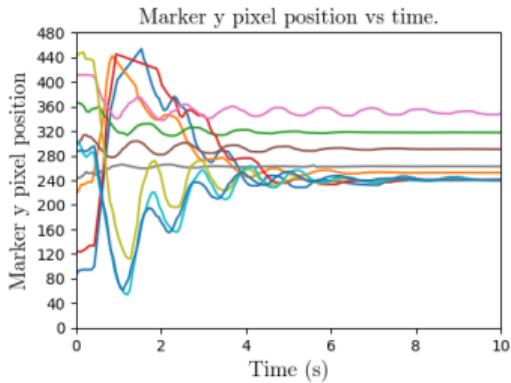
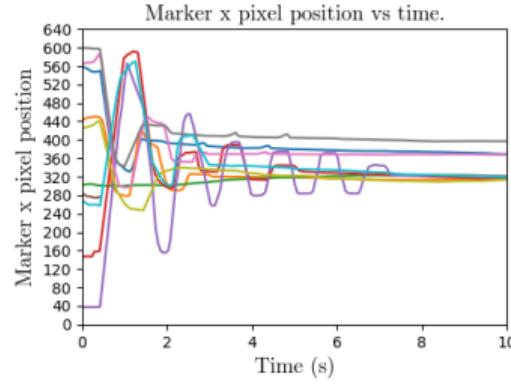
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Test Hexacopters' Performance

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- ~20 min flying time
- Successful marker tracking
- Errors during approach
 - Monocular pose estimation ambiguity
 - GPS inaccuracy
- No successful autonomous landing
(but almost)



Heavy Lift IR Drone

- Project with Christopher Hamilton (geologist, University of Arizona) and Baldur Björnsson



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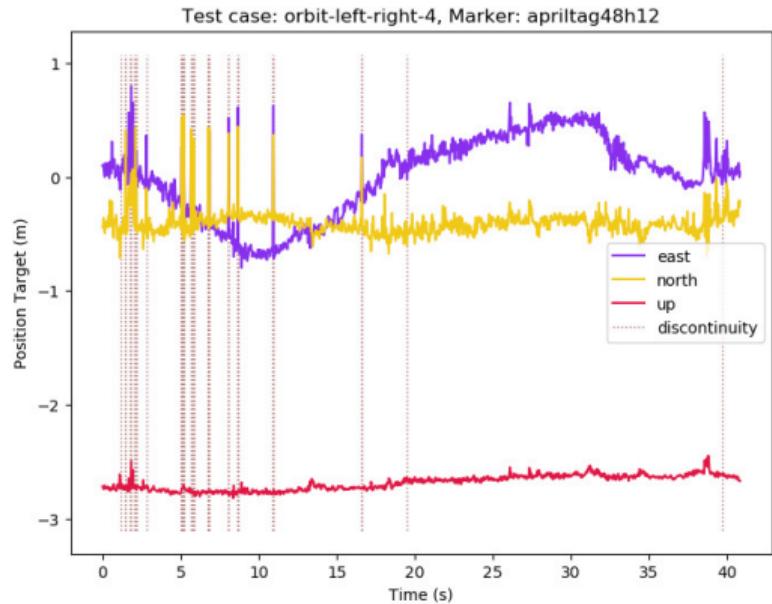
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- Featured on BBC Click



Fiducial System Modifications

Necessary properties:

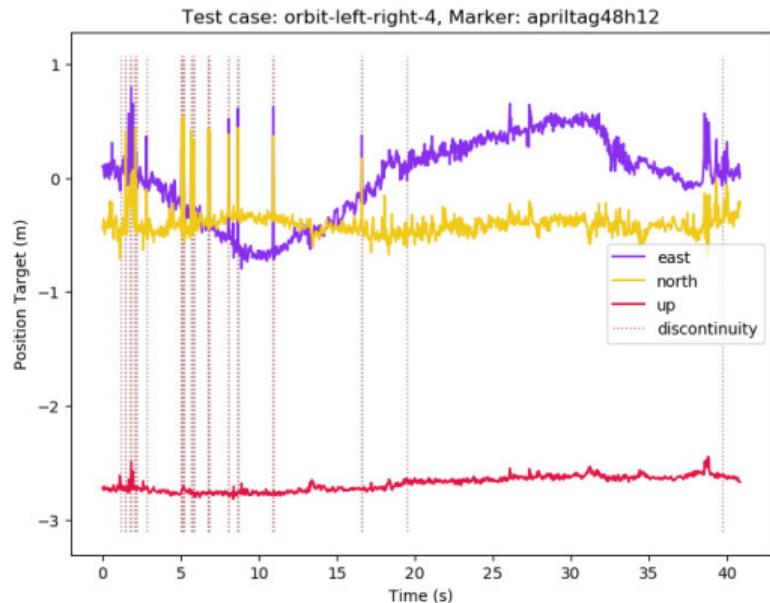
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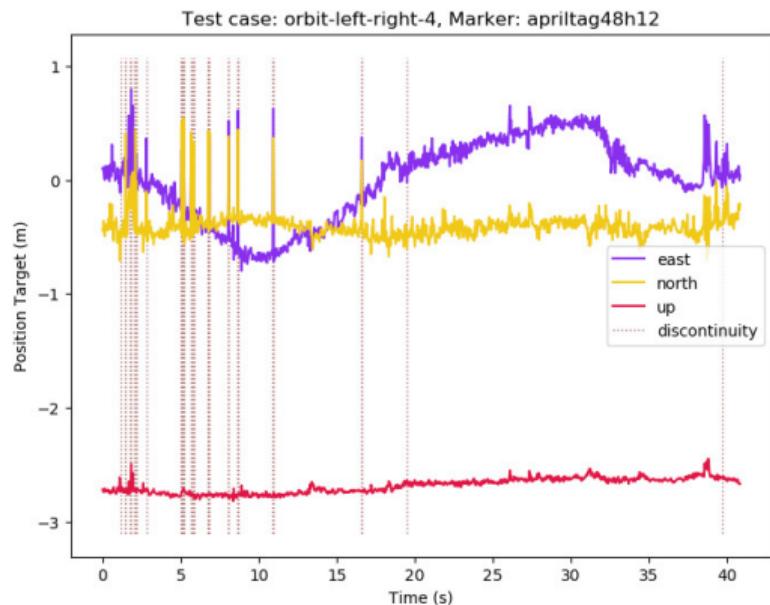
- Mitigates orientation ambiguity
- Detectable at long- and short-range



Fiducial System Modifications

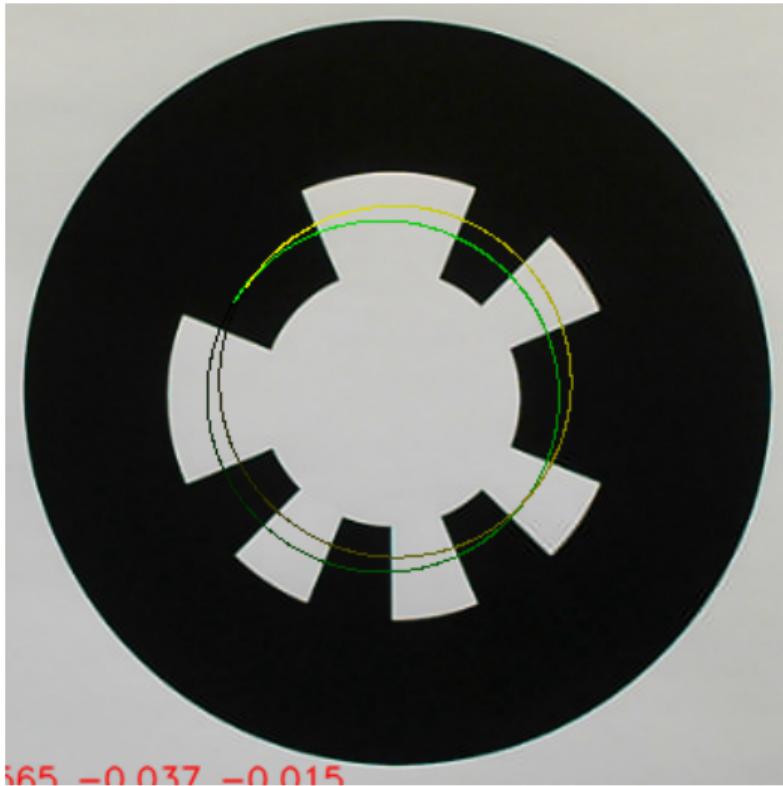
Necessary properties:

- Mitigates orientation ambiguity
- Detectable at long- and short-range
- Runs on embedded hardware



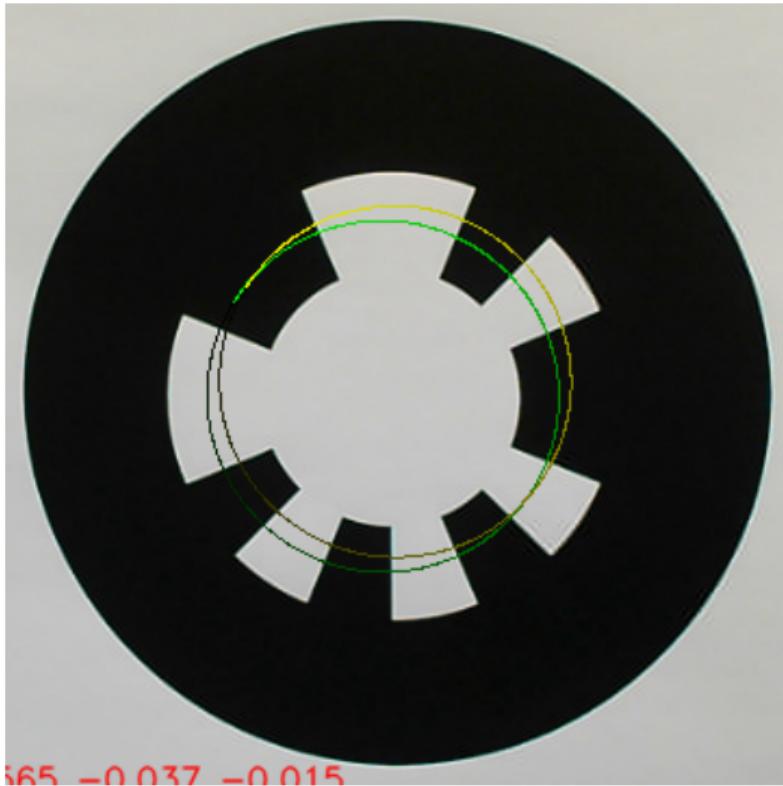
Orientation Ambiguity in WhyCode

- Semi-axes → 2 possible orientations



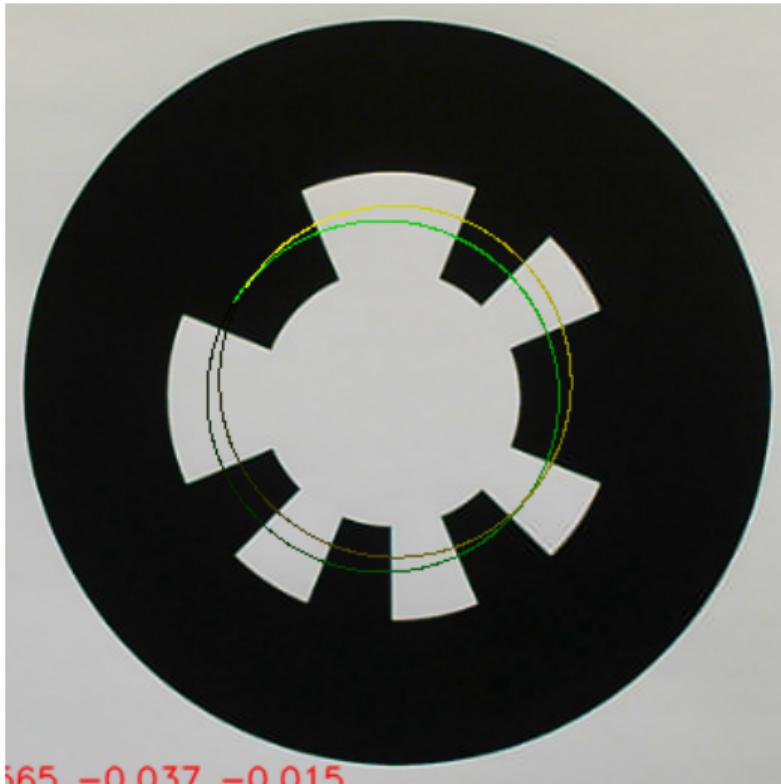
Orientation Ambiguity in WhyCode

- Semi-axes → 2 possible orientations
- Better centered → correct



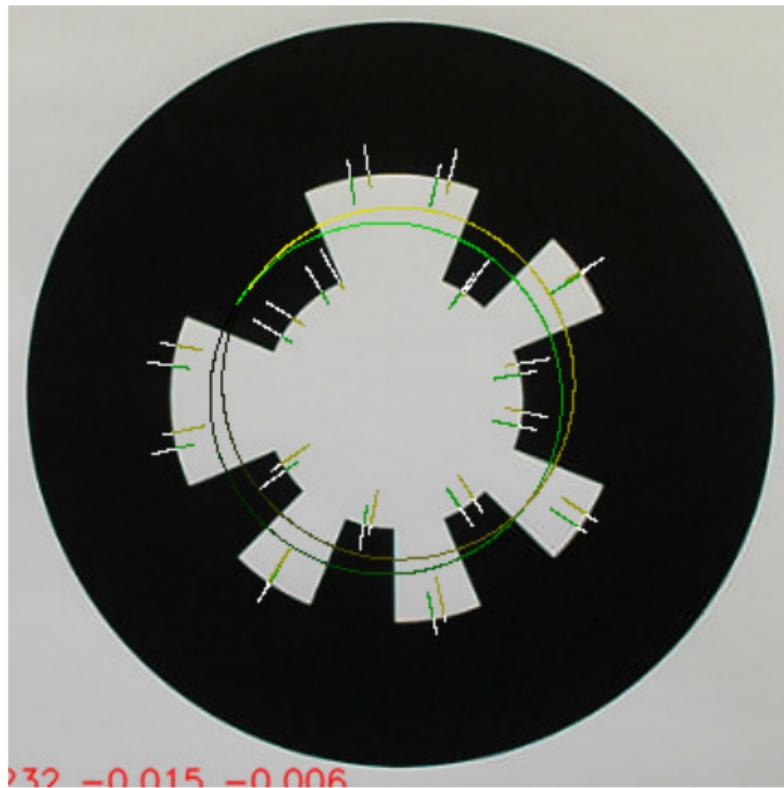
Orientation Ambiguity in WhyCode

- Semi-axes → 2 possible orientations
- Better centered → correct
- Arclength of intersections with ID “teeth”



Fiducial System Modifications: “WhyCode Ellipse”

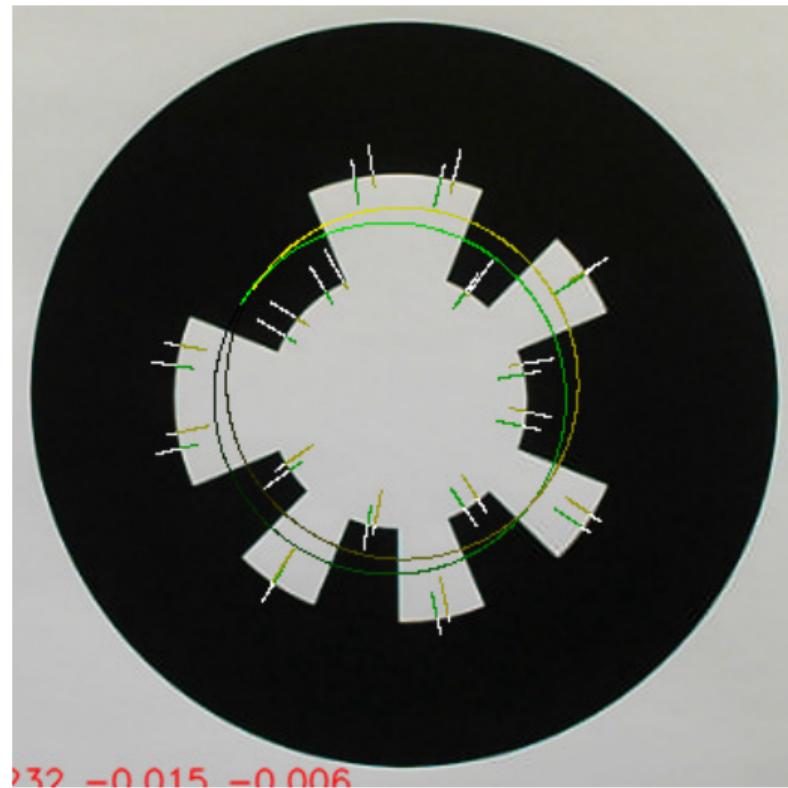
Approach 1: Extra tooth sampling



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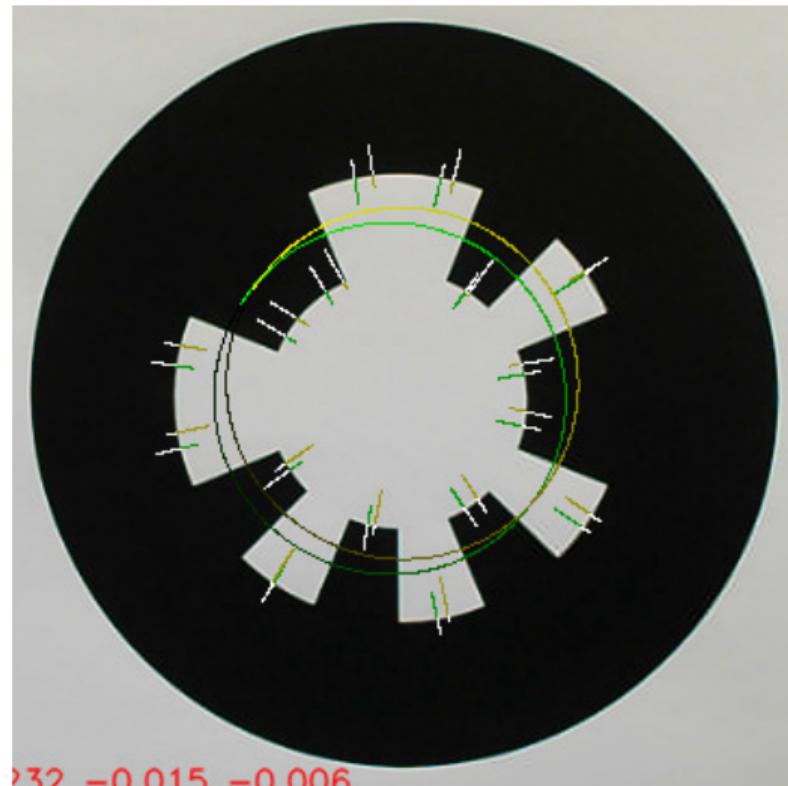
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- Add: radial sampling on tooth edges.

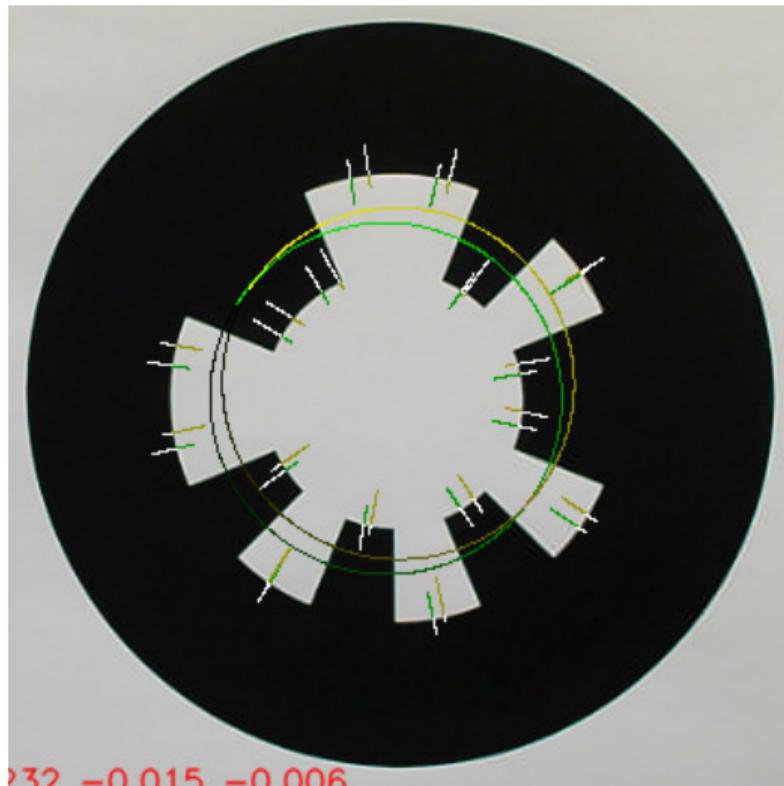


032 -0.015 -0.006

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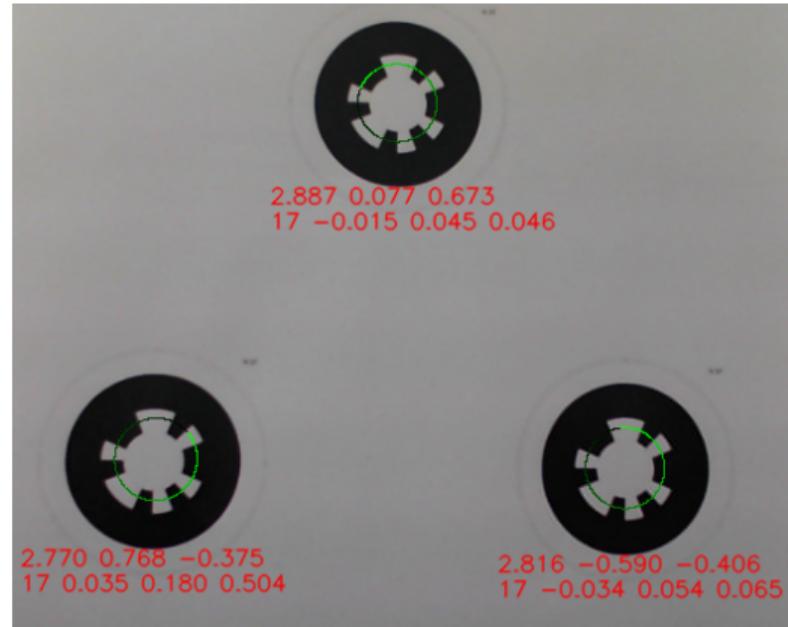
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- Choose solution based on tooth edge predictions.



Fiducial System Modifications: “WhyCode Multi”

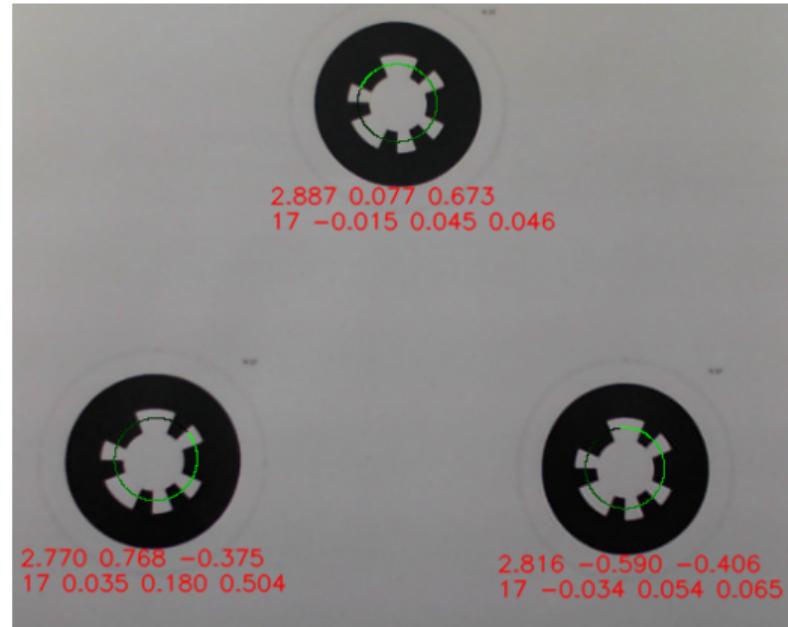
Approach 2: Coplanar marker arrangements



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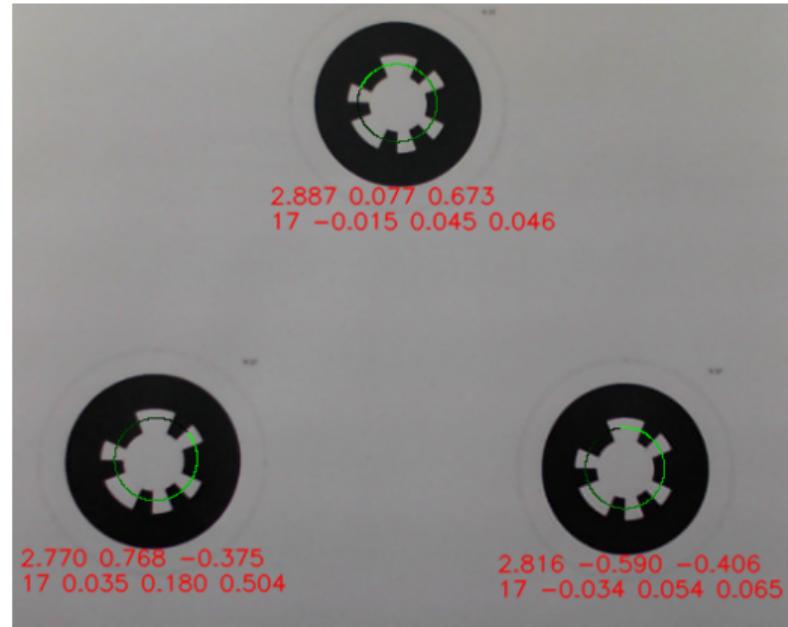
- Ignore individual marker orientations



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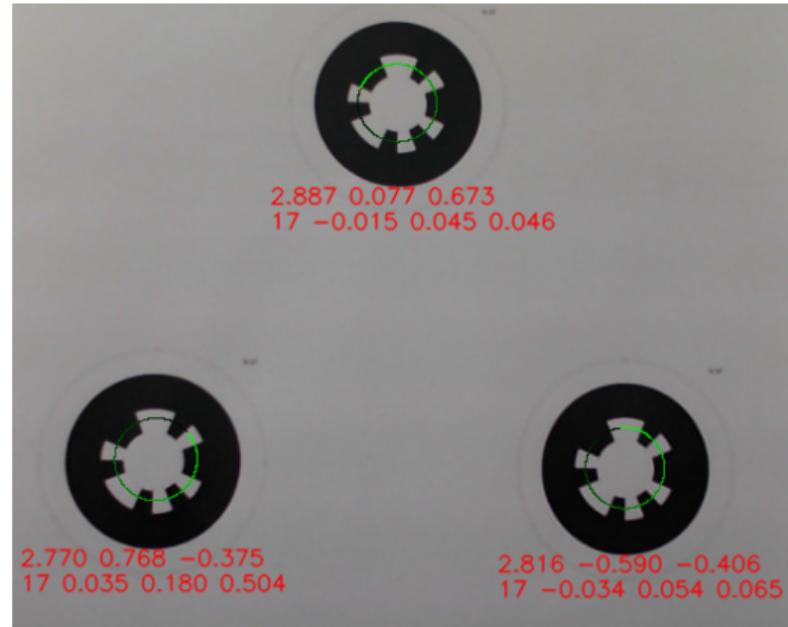
- Ignore individual marker orientations
- Calculate normal vector to the plane connecting the markers.



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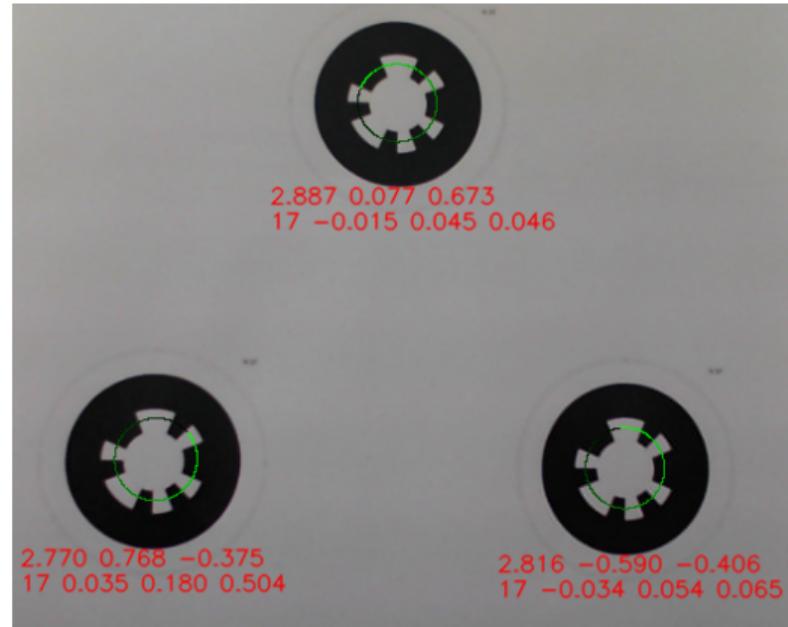
- Ignore individual marker orientations
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- Extract pitch and roll from the normal vector.



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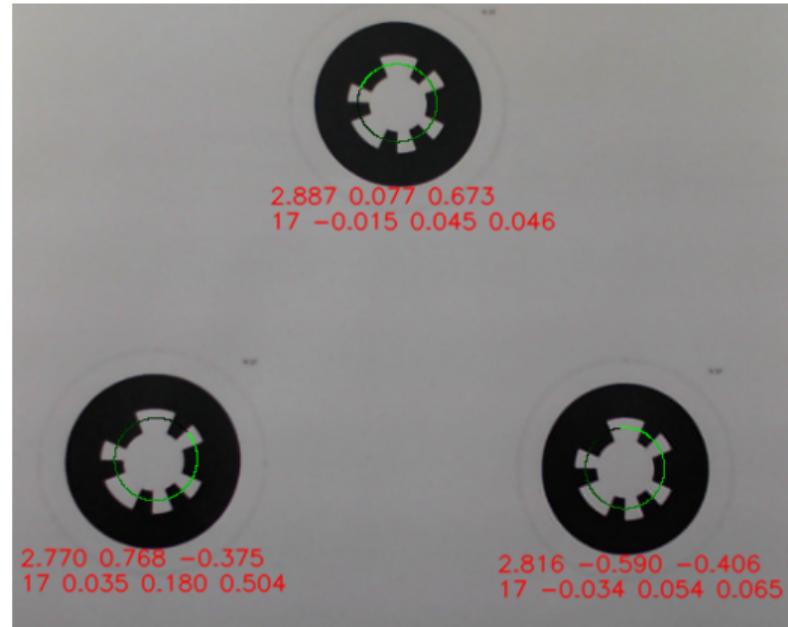
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- Extract pitch and roll from the normal vector.
- Extract yaw from the marker IDs.
- Takes advantage of WhyCode’s efficiency.



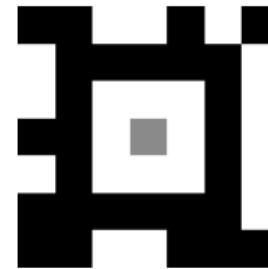
Fiducial System Modifications: April Tag

April Tag: less orientation ambiguity, but less computationally efficient.

April Tag 48h12: more sophisticated, “recursive.”

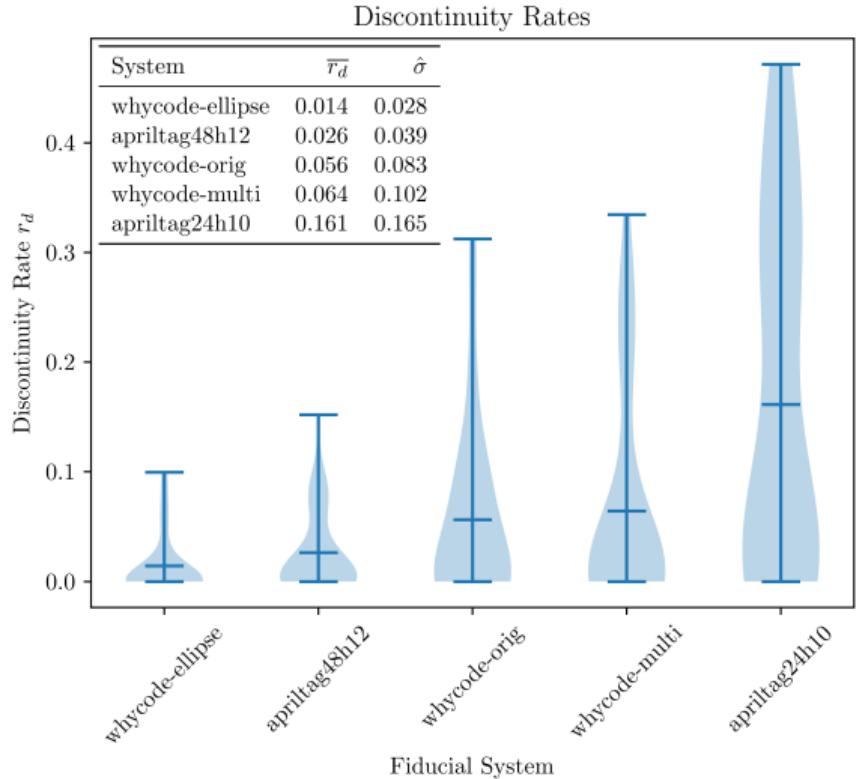


April Tag Custom 24h10: “recursive,” smaller definition



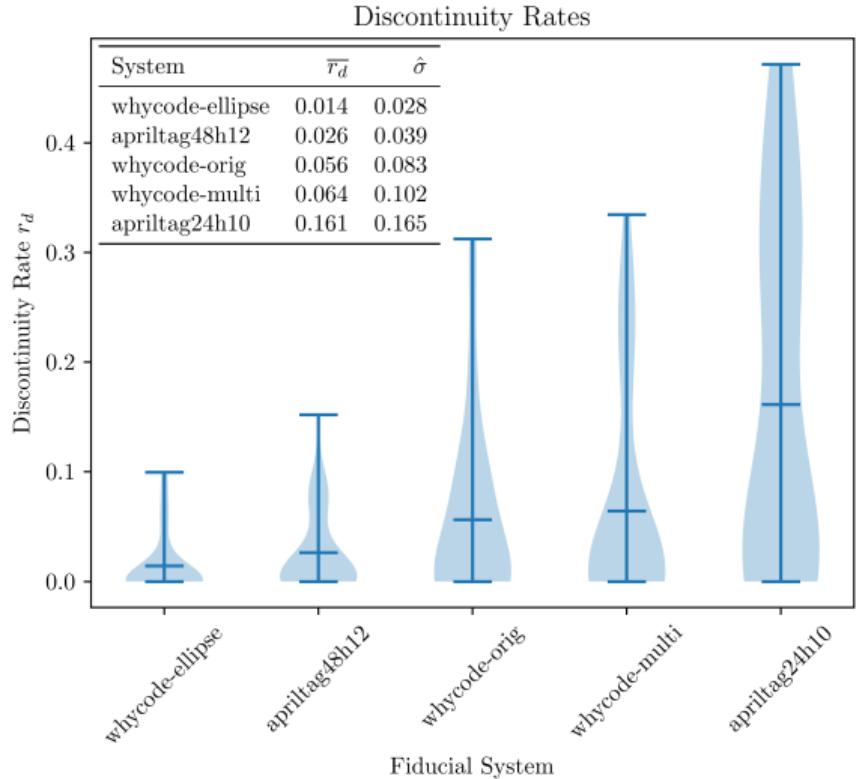
Performance Analysis: Discontinuity Rates

- Discontinuity rate \bar{r}_d is the number of discontinuities per detection.



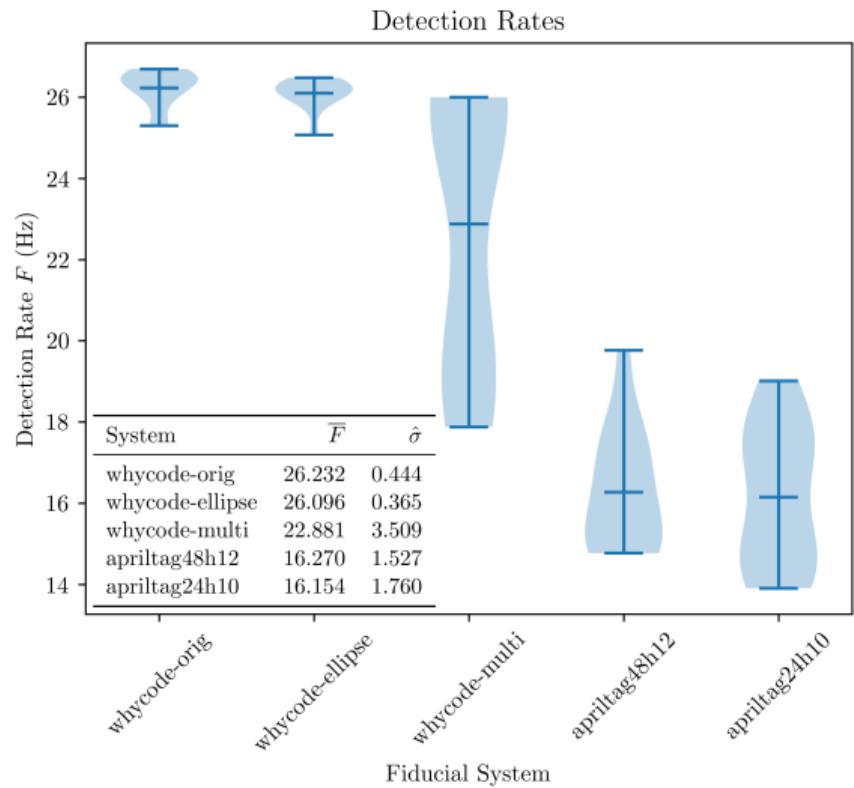
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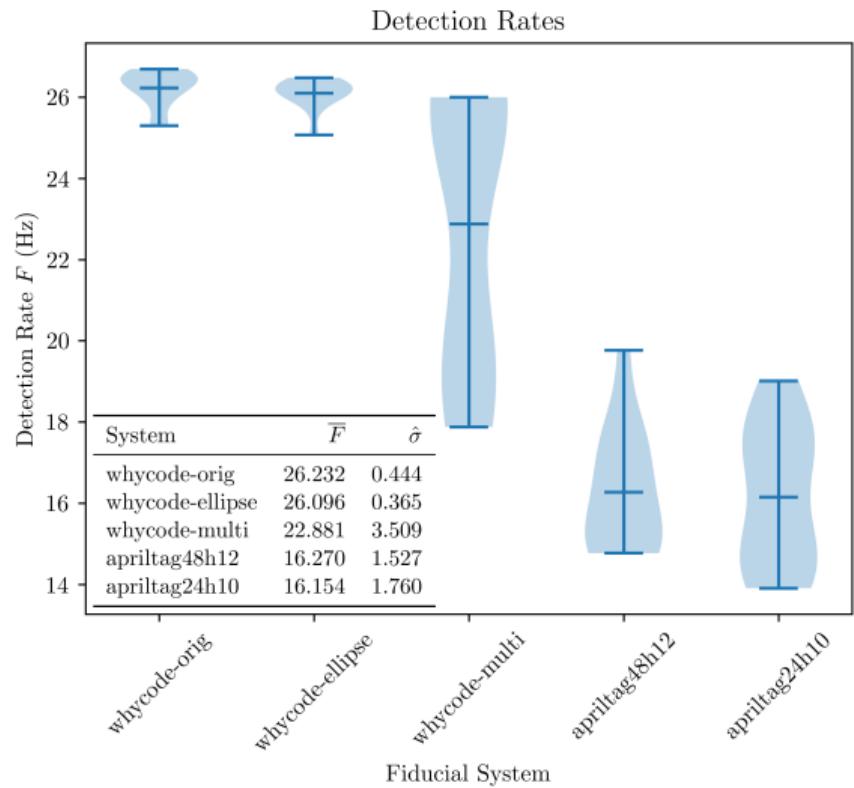
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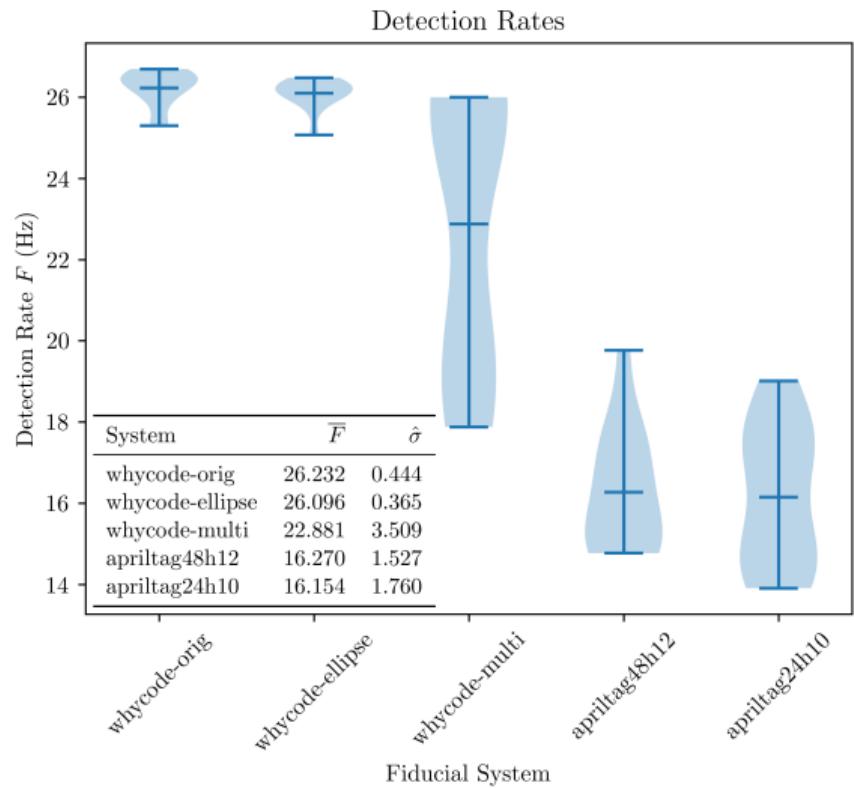
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Performance Analysis: Detection Rates

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- Indoor experiments with DJI Spark



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 - Reduces logistical considerations: transportation, weather



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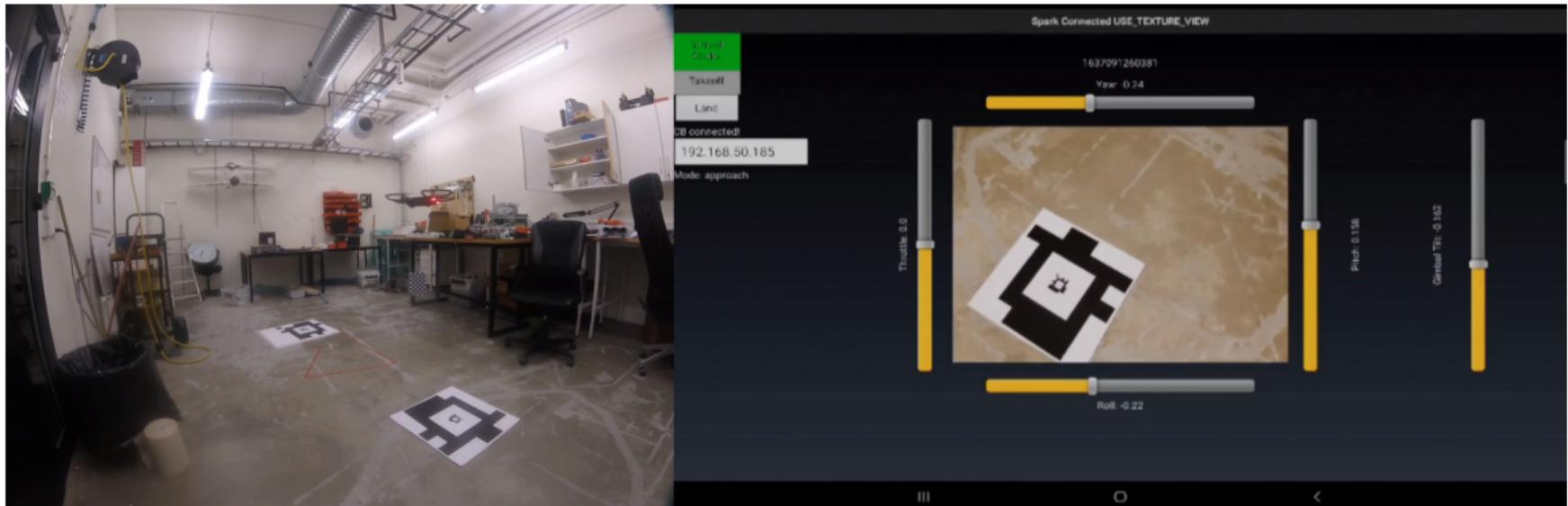


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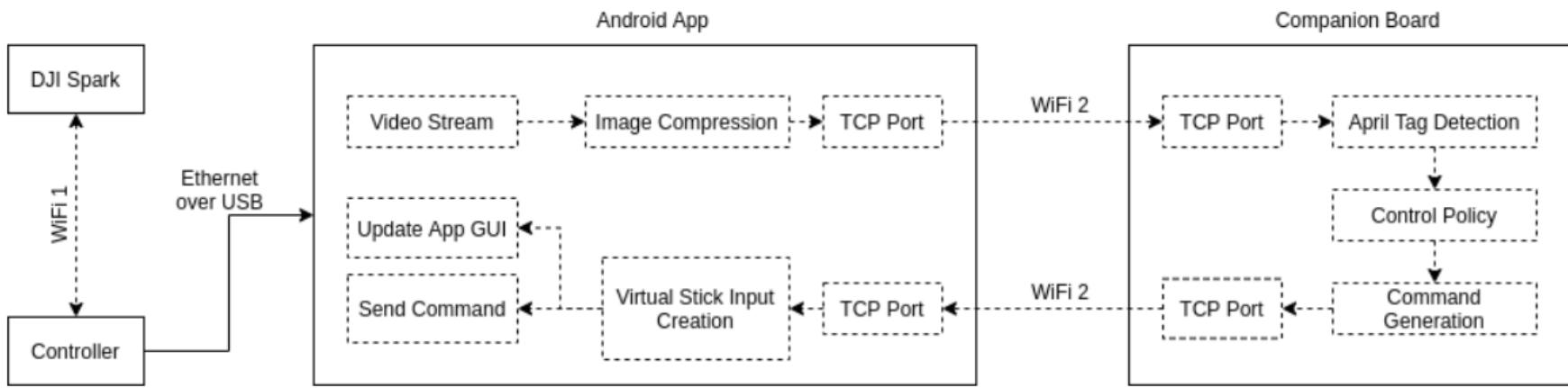
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- Limiting factor: pre-transmission image compression on tablet (6-7 Hz)



Demo with worst-performing April Tag 24h10!



Autonomous Landing Proof of Concept: System Architecture



Publications

- Submitted: Evaluation of April Tag and WhyCode Fiducial Systems for Autonomous Precision Drone Landing with a Gimbal-Mounted Camera
- In Progress: Proof of Concept Results



Research Plan



Overview: Unstructured Autonomous Landing



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- Focus on terrain analysis



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 - Input: sensor data
 - Process (quickly): ??
 - Output: safe landing sites (e.g. heat map)



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Data Set Generation

AirSim: realistic simulator

- Automatic generation of large data sets

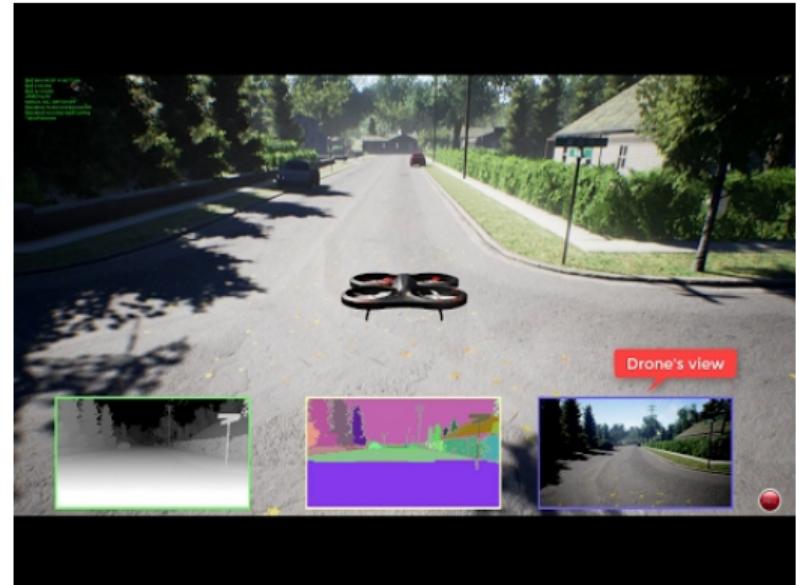


Image source



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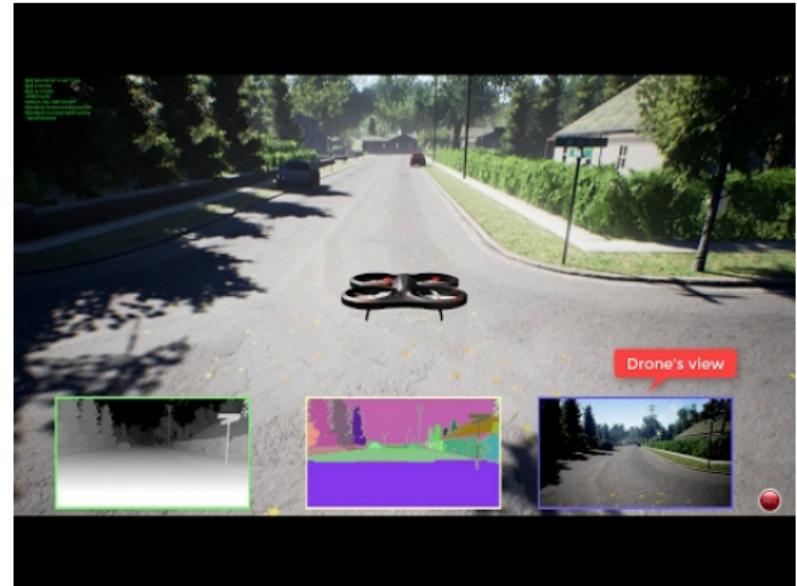


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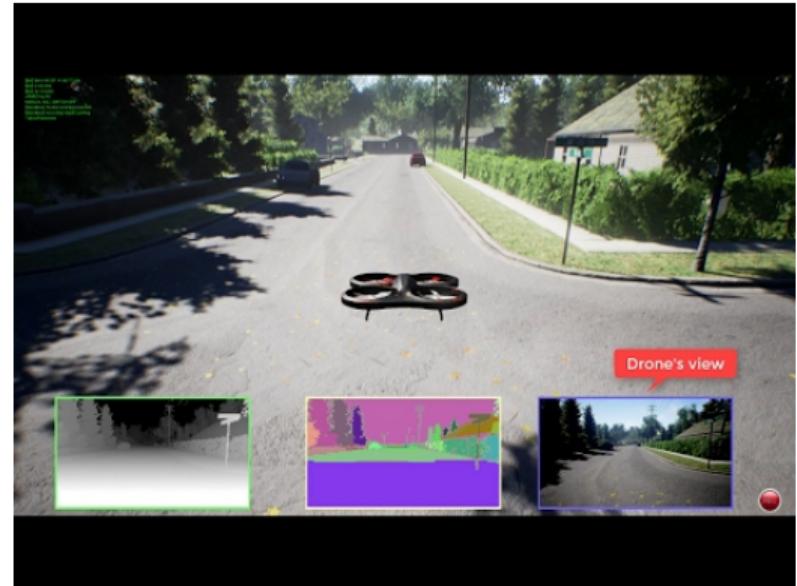


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 - LIDAR → RADAR

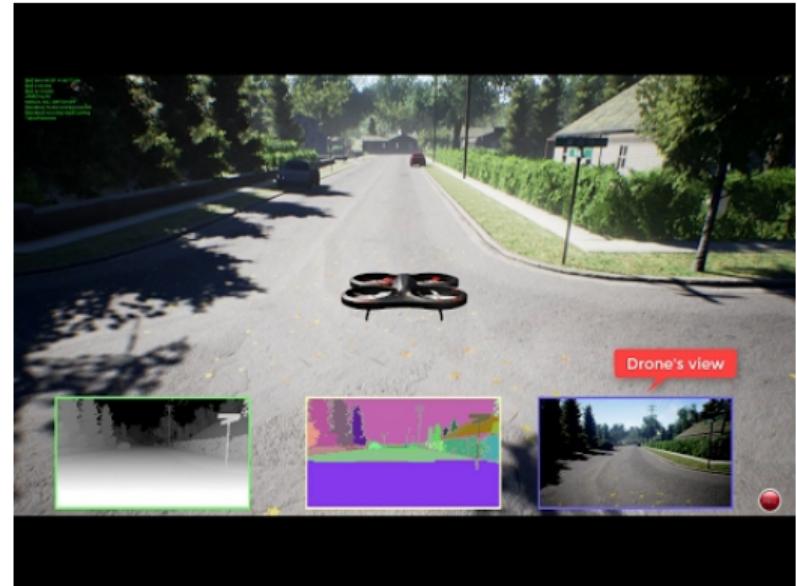


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 - LIDAR → RADAR
- Specify realistic sensor parameters

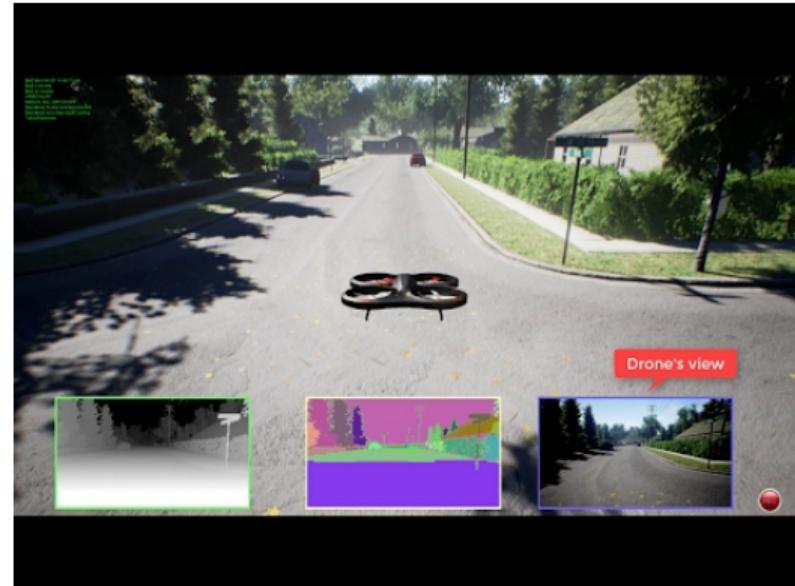


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 - LIDAR → RADAR
- Specify realistic sensor parameters
- Segmentation masks for high-level label generation

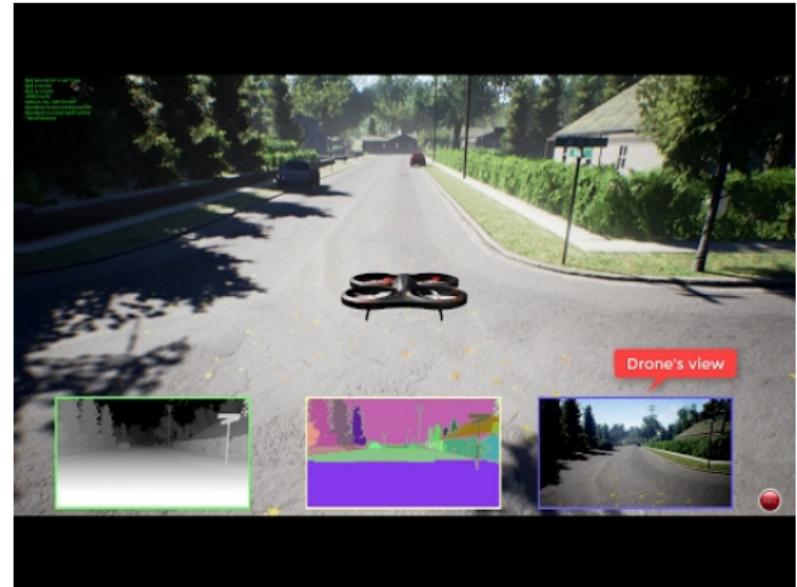


Image source



Data Set Generation

AirSim: realistic simulator

- Automatic generation of large data sets
- Synthetic sensor data (LIDAR, RGBD cameras)
- Tag with IMU data
 - LIDAR → RADAR
- Specify realistic sensor parameters
- Segmentation masks for high-level label generation
- Labeling method can be slow, hand-tuned

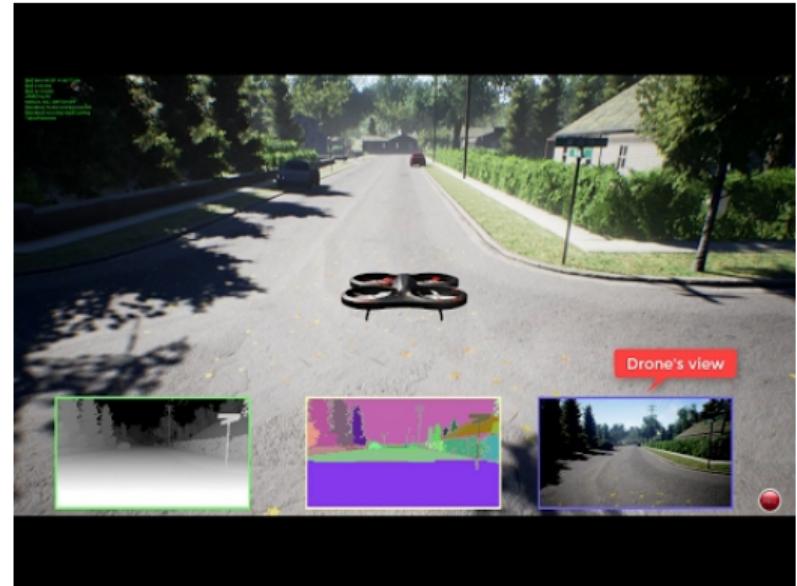


Image source



Terrain Classifier Creation

- Test several methods



Terrain Classifier Creation

- Test several methods
 - Conventional signal/image processing



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 - Deep learning methods



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 - Downsampling/resizing



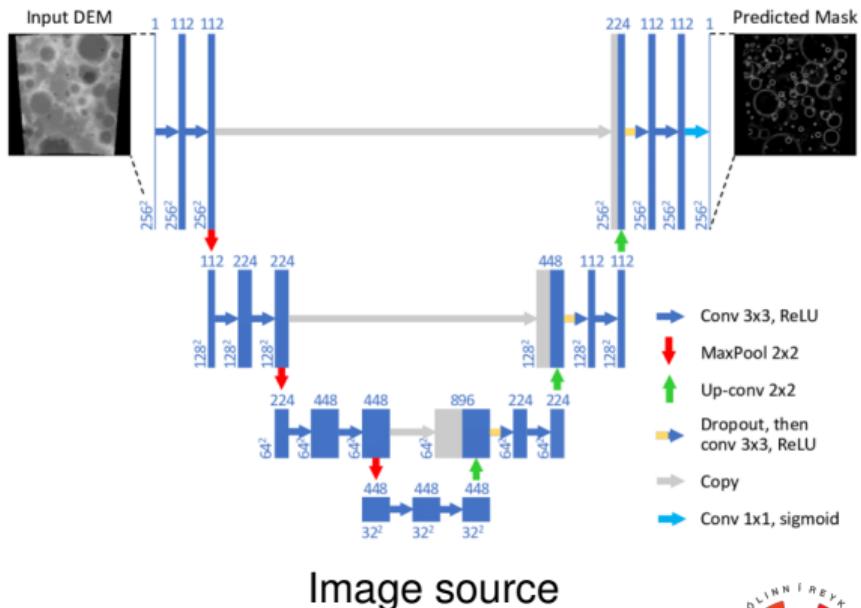
Terrain Classifier Creation

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 - Conventional signal/image processing
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Testing in Simulation

- Post-processing wrappers:
 - Safe region tracking



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 - Does the autopilot software accept the commands?



Simulation is not enough!



Testing in the Real World

- Offline
 - Accuracy on real world data

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- Lab scenarios
 - Runtime framerate on embedded hardware
 - Power requirements on embedded hardware



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- Real world landing scenarios



Drone Upgrades

- New flight controller: Pixhawk Cube Orange



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 - Optical Flow
 - LIDAR rangefinder



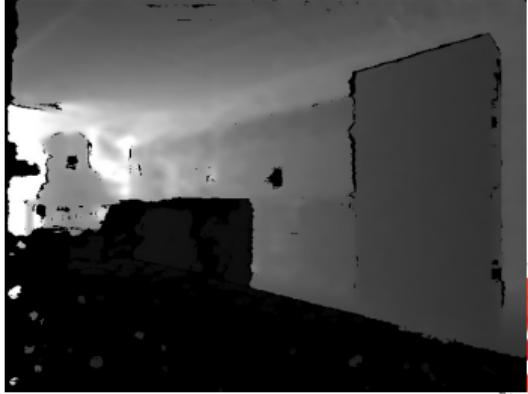
Drone Upgrades

- New flight controller: Pixhawk Cube Orange
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- Protective sensor cases, gimbal mounts



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 - Intel RealSense D455 RGBD camera (IMU)
 - Intel RealSense L515 LIDAR (IMU)
 - Texas Instruments IWR6843 60 GHz RADAR



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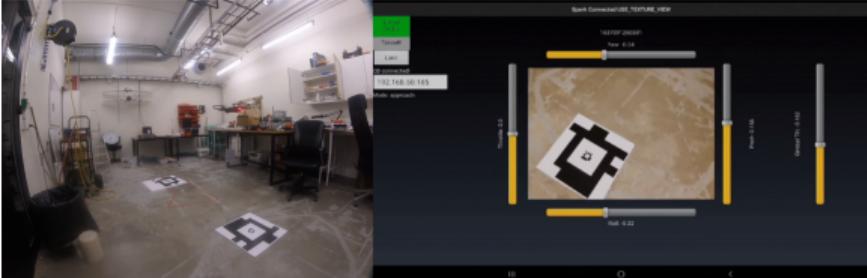
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 - Use non-embedded hardware → generate reliable flight commands on real world data



Summary

- Goal: autonomous drone landing

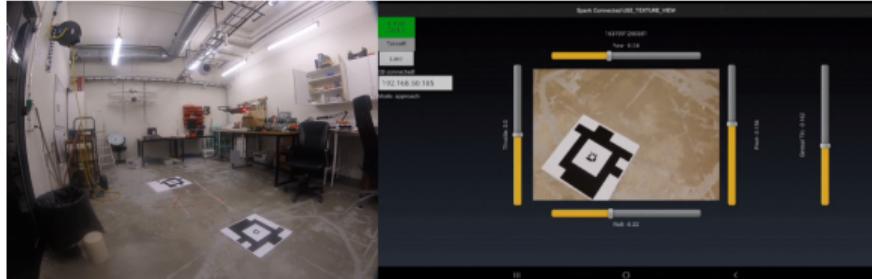


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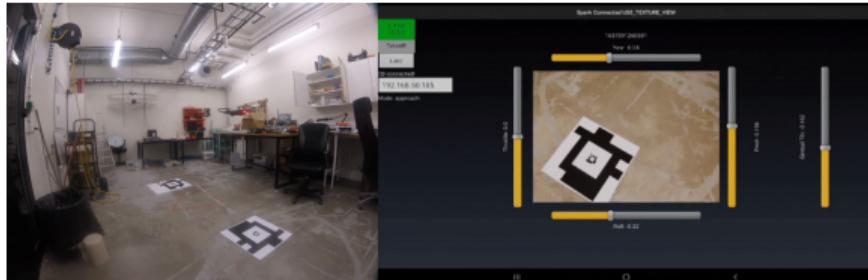


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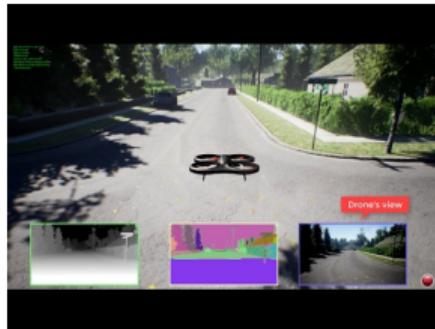


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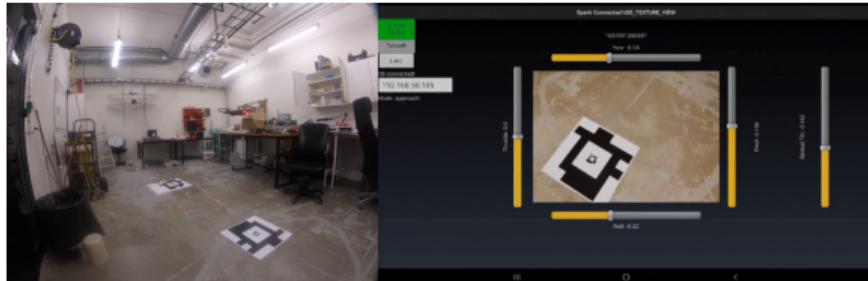


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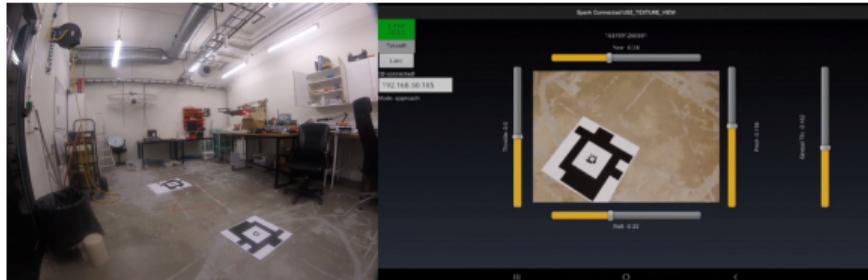


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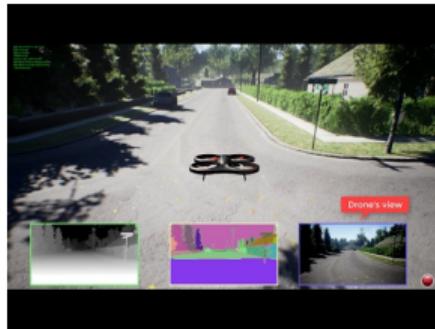


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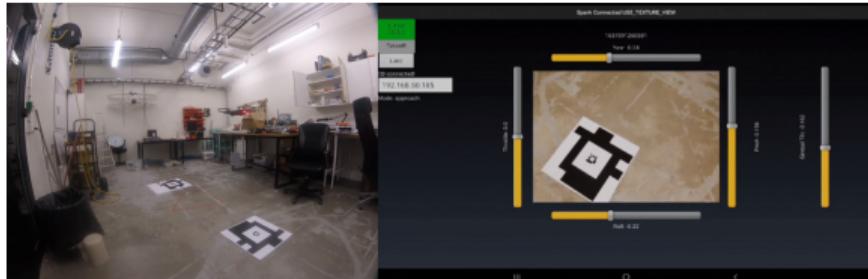


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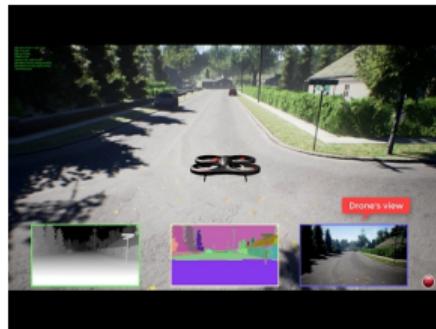


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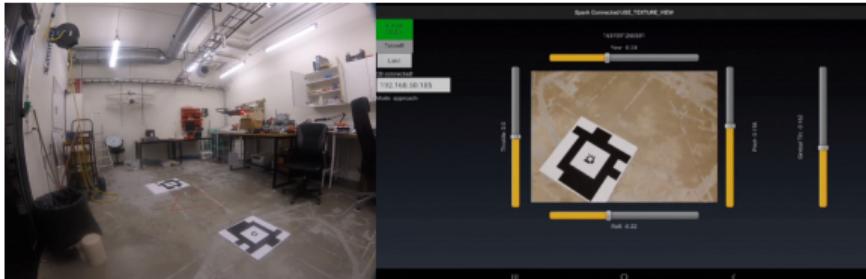


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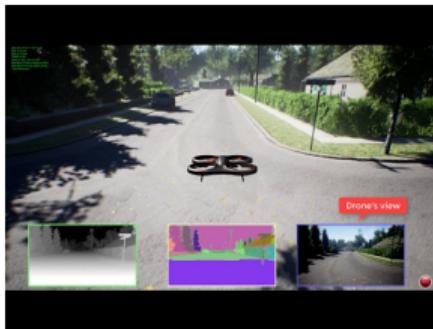


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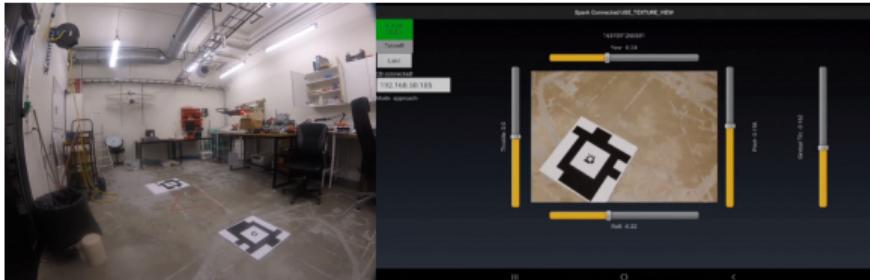


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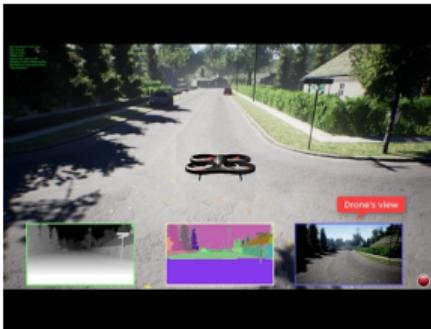


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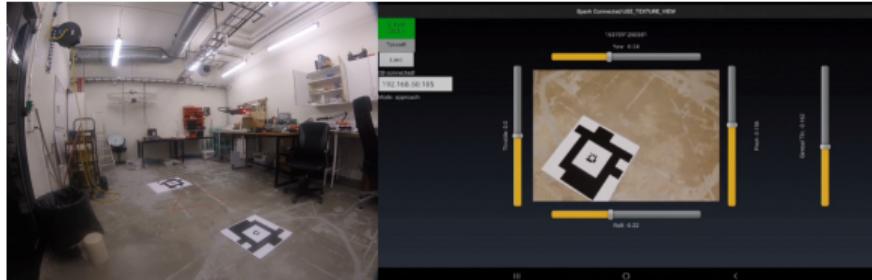


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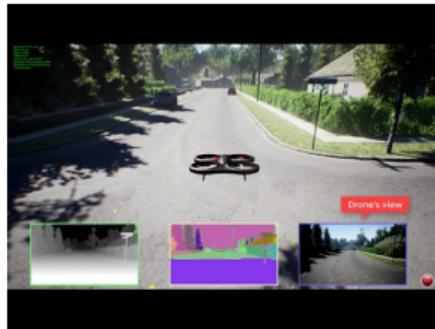


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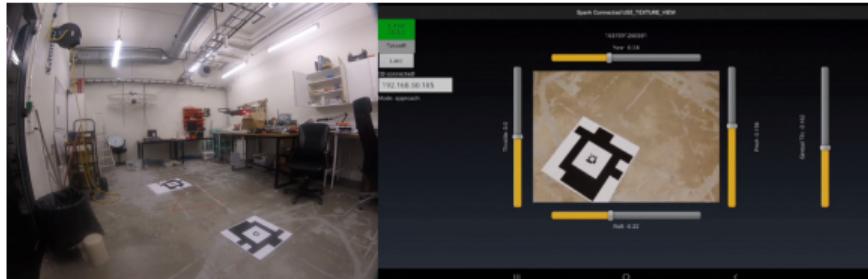


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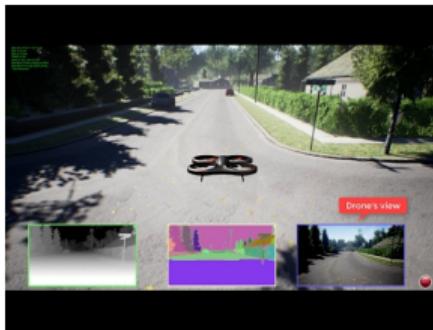


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- Thank you! Are there any questions?



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References

