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

(2) Completed/ongoing projects
- Initial proof of concept attempt
  - Continuation of master thesis (tested in simulation)
- 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"

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- How can those methods execute in real time onboard a drone?

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- Other methods

Completed and Ongoing Projects

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- Two Tarot 680 hexacopters
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Test Hexacopter Components

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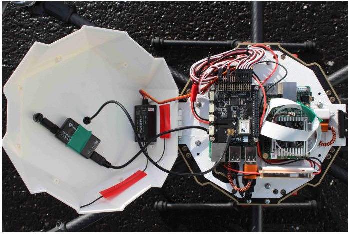

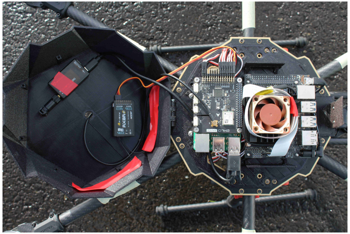

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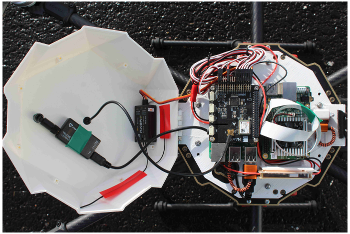

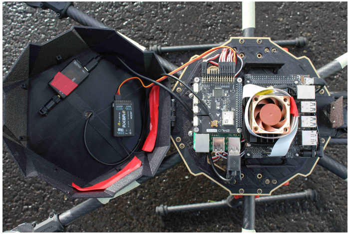

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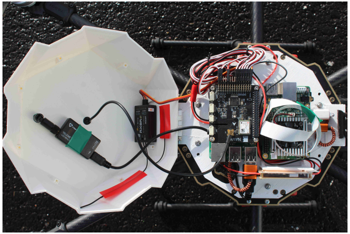

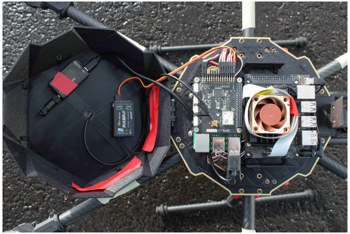

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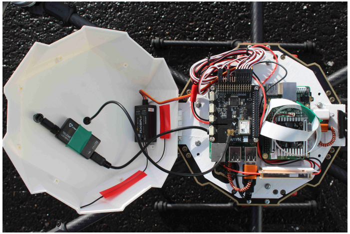

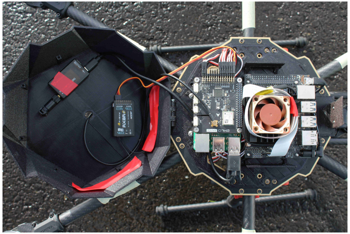

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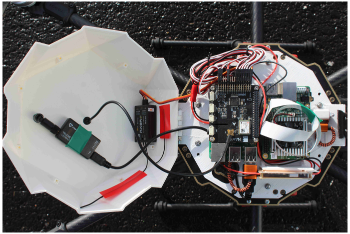

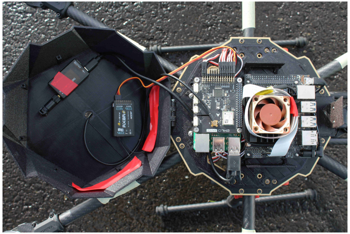

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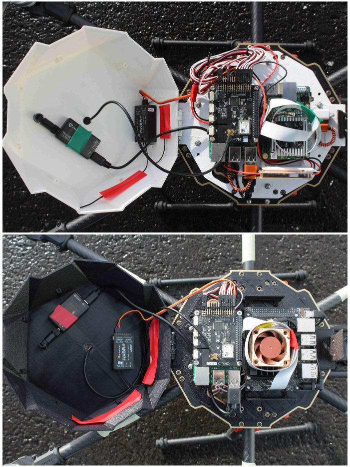

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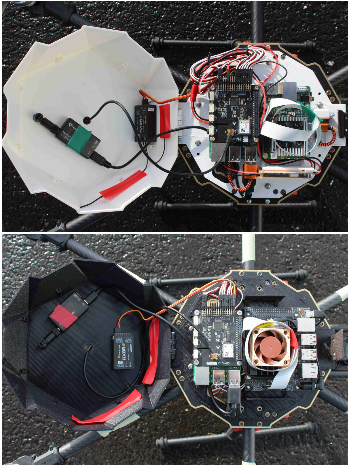

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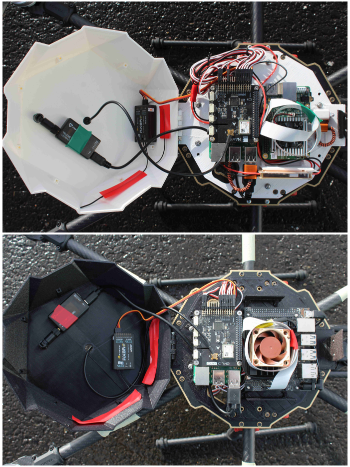

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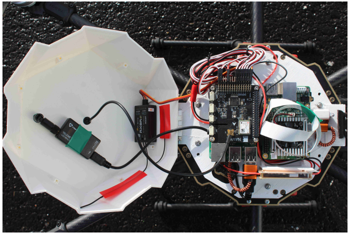
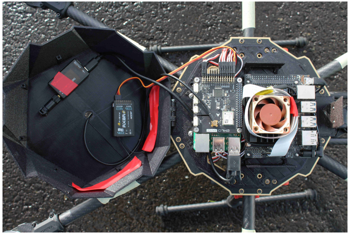
  - PX4 (not technically supported)





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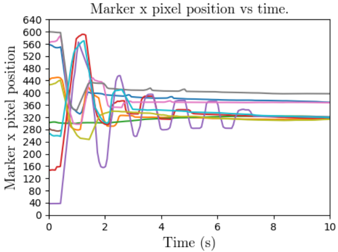
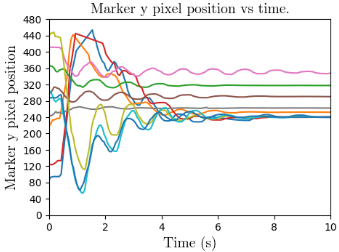
- Errors during approach
  - Monocular pose estimation ambiguity
  - GPS inaccuracy
- No successful autonomous landing (but almost)





Heavy Lift IR Drone

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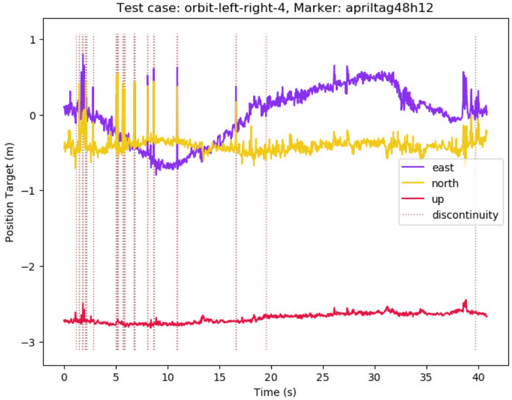
- Featured on BBC Click

Fiducial System Modifications

Necessary properties:

- Mitigates orientation ambiguity



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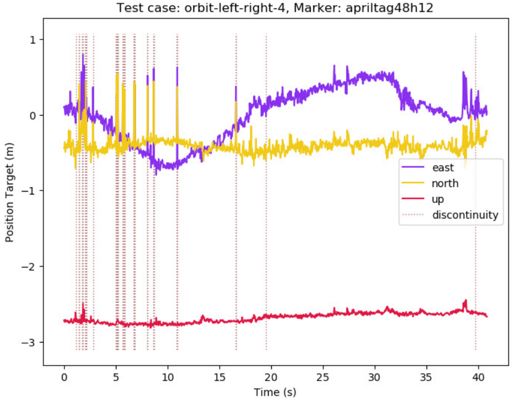

Fiducial System Modifications

Necessary properties:

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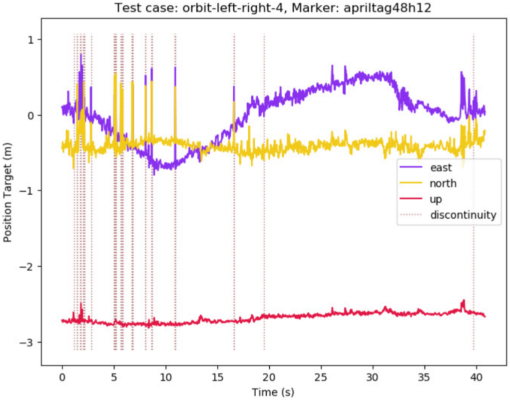
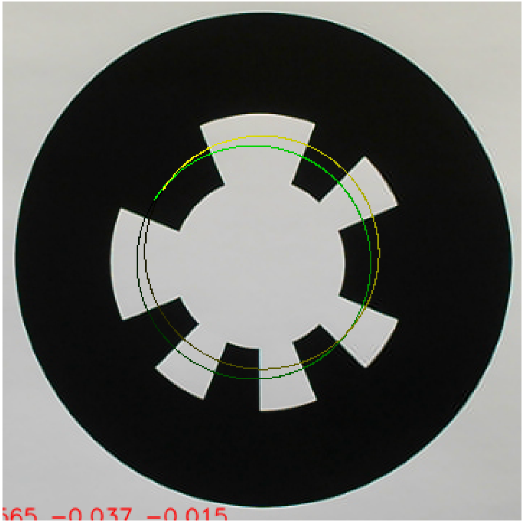


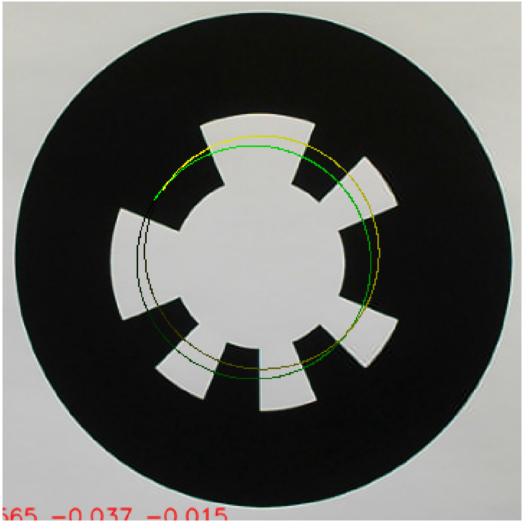
Orientation Ambiguity in WhyCode

- Semi-axes $\rightarrow$ 2 possible orientations



Orientation Ambiguity in WhyCode

- Semi-axes $\rightarrow$ 2 possible orientations
- Better centered $\rightarrow$ correct



Orientation Ambiguity in WhyCode

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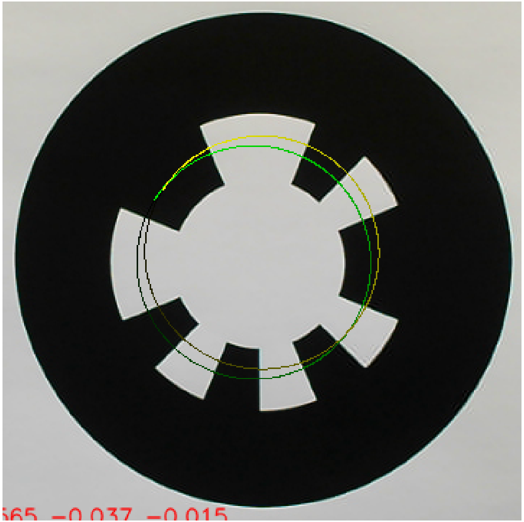
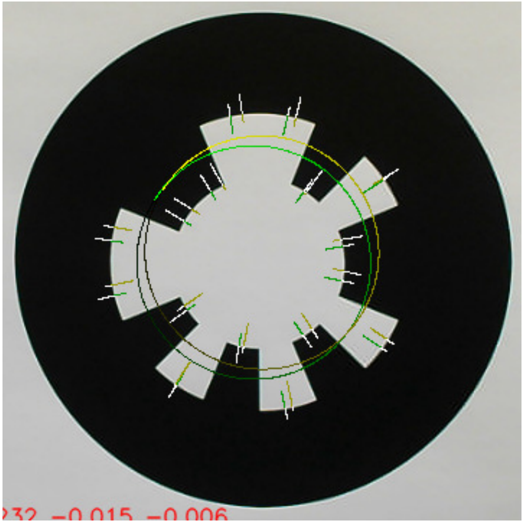
- Arclength of intersections with ID “teeth”



Fiducial System Modifications: “WhyCode Ellipse”

Approach 1: Extra tooth sampling



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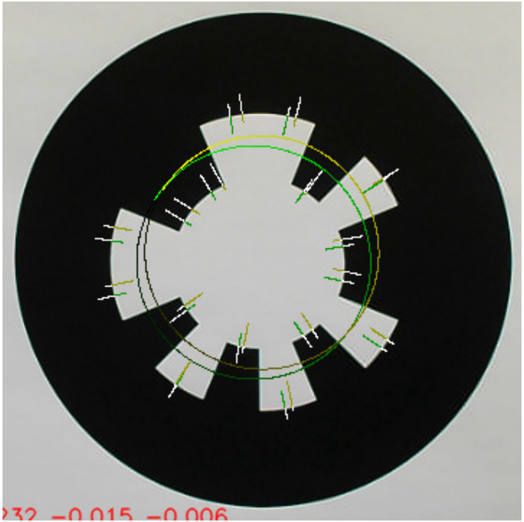

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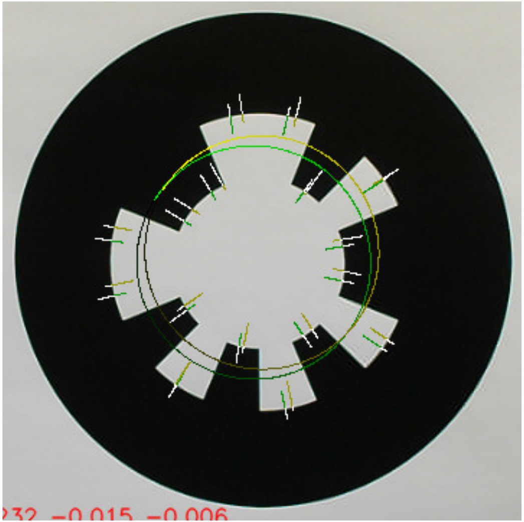

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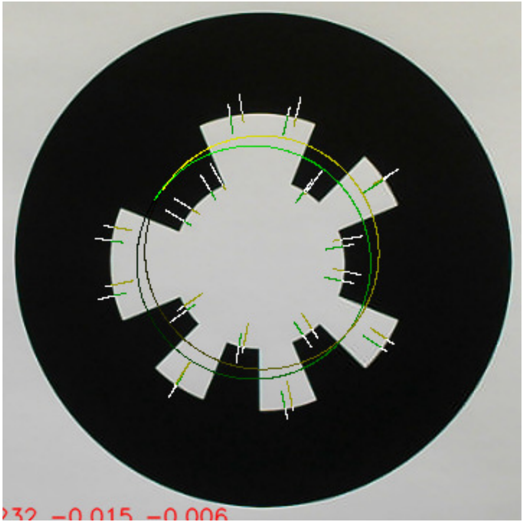

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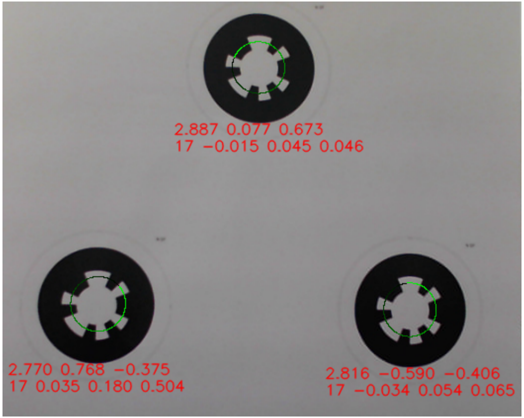
Approach 2: Coplanar marker arrangements



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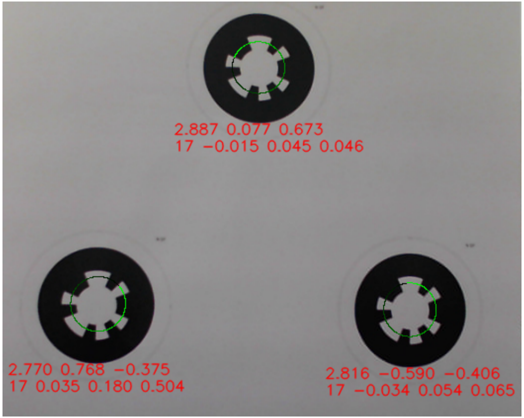

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- Ignore individual marker orientations
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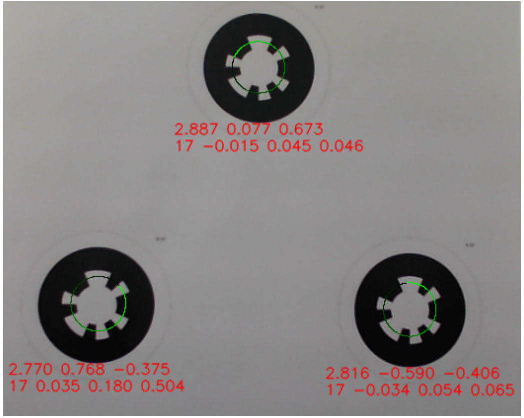

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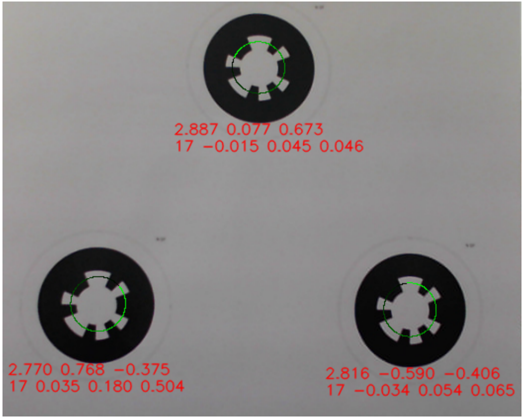

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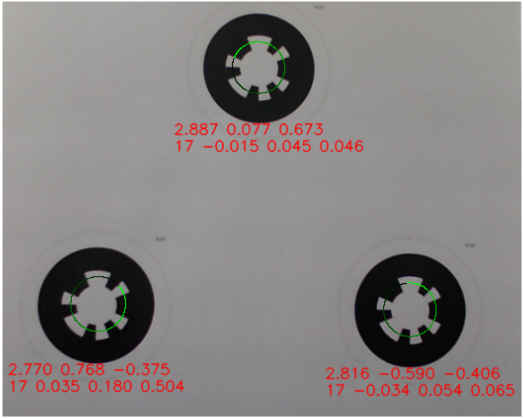

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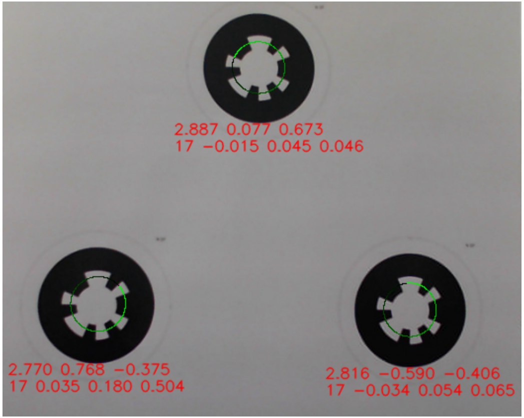
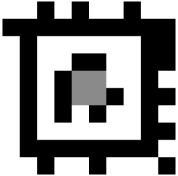
- Takes advantage of WhyCode’s efficiency.



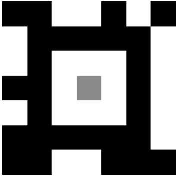
Fiducial System Modifications: April Tag

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

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

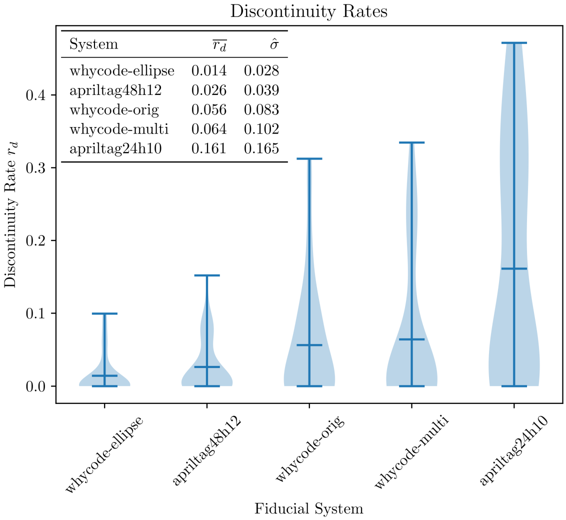


April Tag Custom 24h10: “recursive,” smaller definition



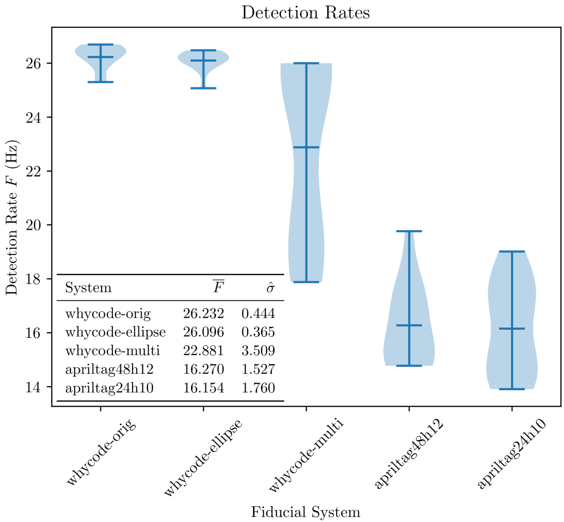
Performance Analysis: Discontinuity Rates

- Orientation ambiguity $\rightarrow$ discontinuities.
- Discontinuity rate $\overline{r_d}$ is the number of discontinuities per detection.
- Lower is better.



Performance Analysis: Detection Rates

- Detection rate $\overline{F}$ is the number of detections per second.
- Tested on Raspberry Pi 4.
- Higher is better.



Autonomous Landing Proof of Concept **(FINALLY!)**

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

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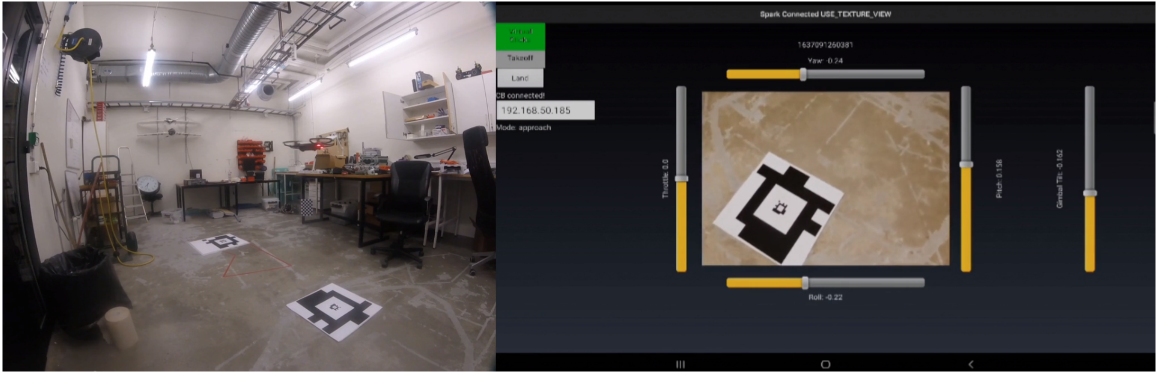
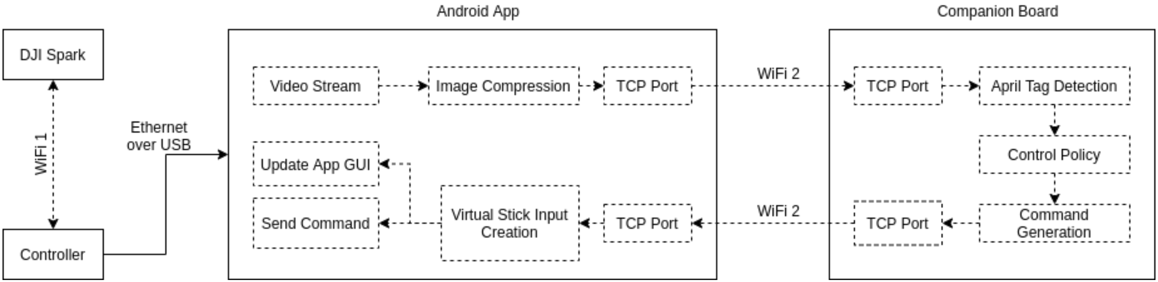
Demo with worst-performing April Tag 24h10!



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: results from autonomous landing proof of concept

Research Plan

Overview: Unstructured Autonomous Landing

- Focus on terrain analysis

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

Overview: Unstructured Autonomous Landing

- Focus on terrain analysis
  - Topographical analysis
  - Semantic segmentation
    - terrain type classification: (snow, ice, water, grass, rock, etc.)
    - classify according to predicted safety: (safe, questionable, unsafe, etc.)
- Focus on real time performance
  - Minimize computational requirements
  - Target specific hardware platforms
- Overall structure:
  - Input: sensor data
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Data Set Generation

AirSim: realistic simulator

- Automatic generation of large data sets

Image source

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- Labeling method can be slow, hand-tuned

Image source

Terrain Classifier Creation

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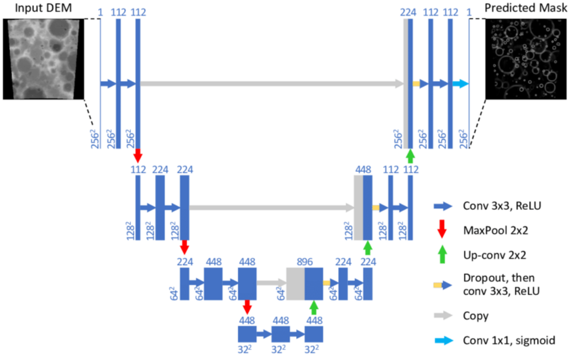

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Simulation is not enough!

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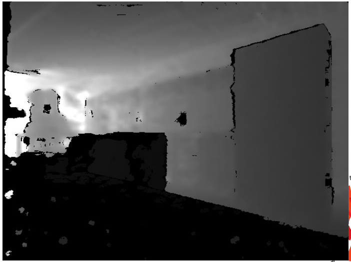
  - Intel RealSense D455 RGBD camera (IMU)
  - Intel RealSense L515 LIDAR (IMU)
  - Texas Instruments IWR6843 60 GHz RADAR



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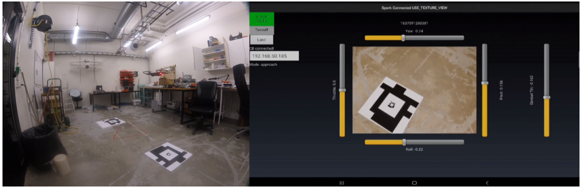
  - Use non-embedded hardware $\rightarrow$ generate reliable flight commands on real world data

Summary

- Goal: autonomous drone landing



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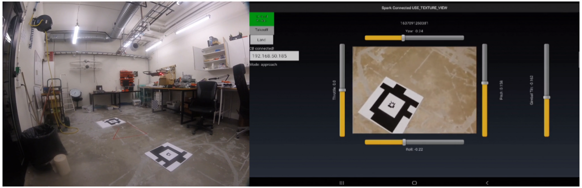

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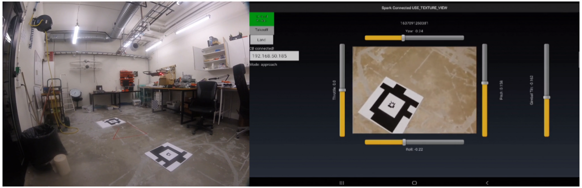

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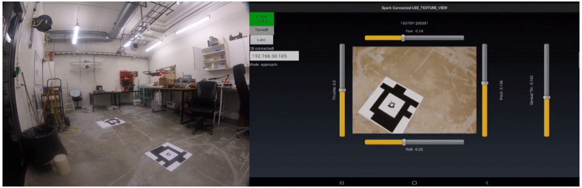

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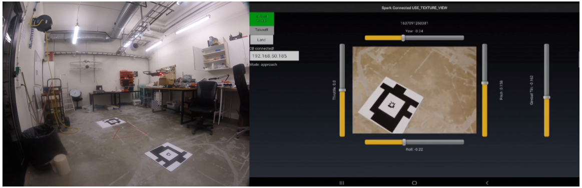

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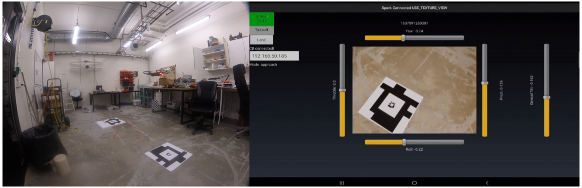

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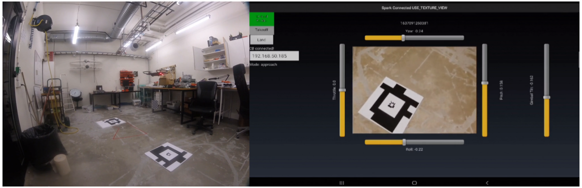

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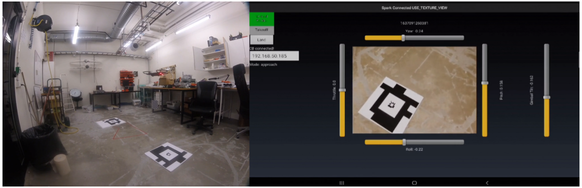

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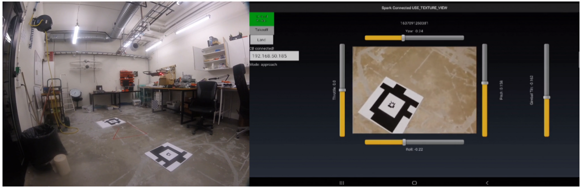

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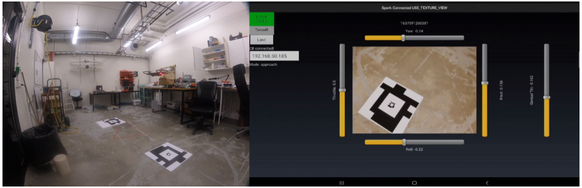

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References