



# Autonomous Multirotor Landing on Landing Pads and Lava Flows

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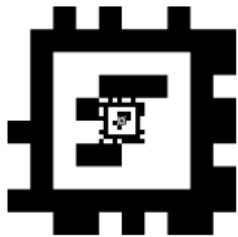
## Topic Overview

- ▶ Autonomous drone landing: hard, needs to be precise
- ▶ Often depends on GPS, blind to obstacles
- ▶ Often needs to be more precise than GPS (or GPS-denied)
- ▶ Landing pads: fiducial markers
- ▶ Terrain analysis
- ▶ Aesthetics:
  - ▶ GPS-independent
  - ▶ Embedded processing only → efficient, quick, dedicated hardware
  - ▶ No active ground infrastructure (e.g. ground stations with telemetry, computing hardware)
  - ▶ Prefer passive sensors (e.g. RGBD cameras instead of LIDAR/RADAR)

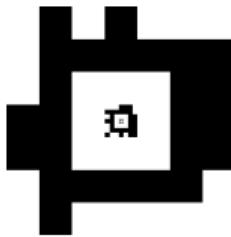
## Structured Case: Landing Pads

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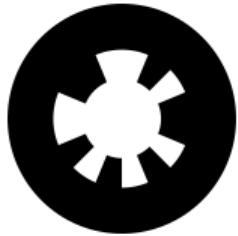
# Fiducial Markers



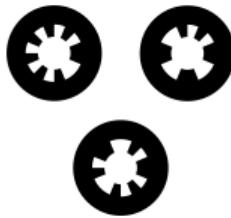
April Tag 48h12



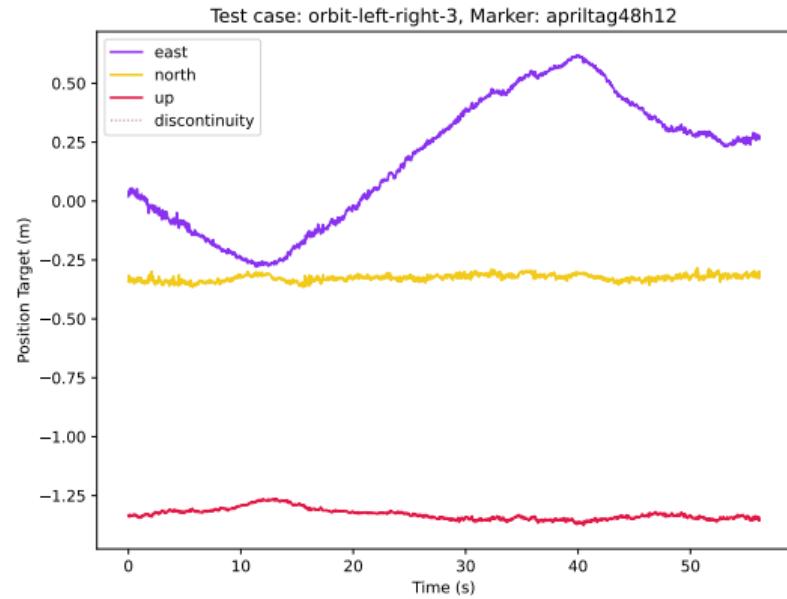
April Tag 24h10



WhyCode (Orig)

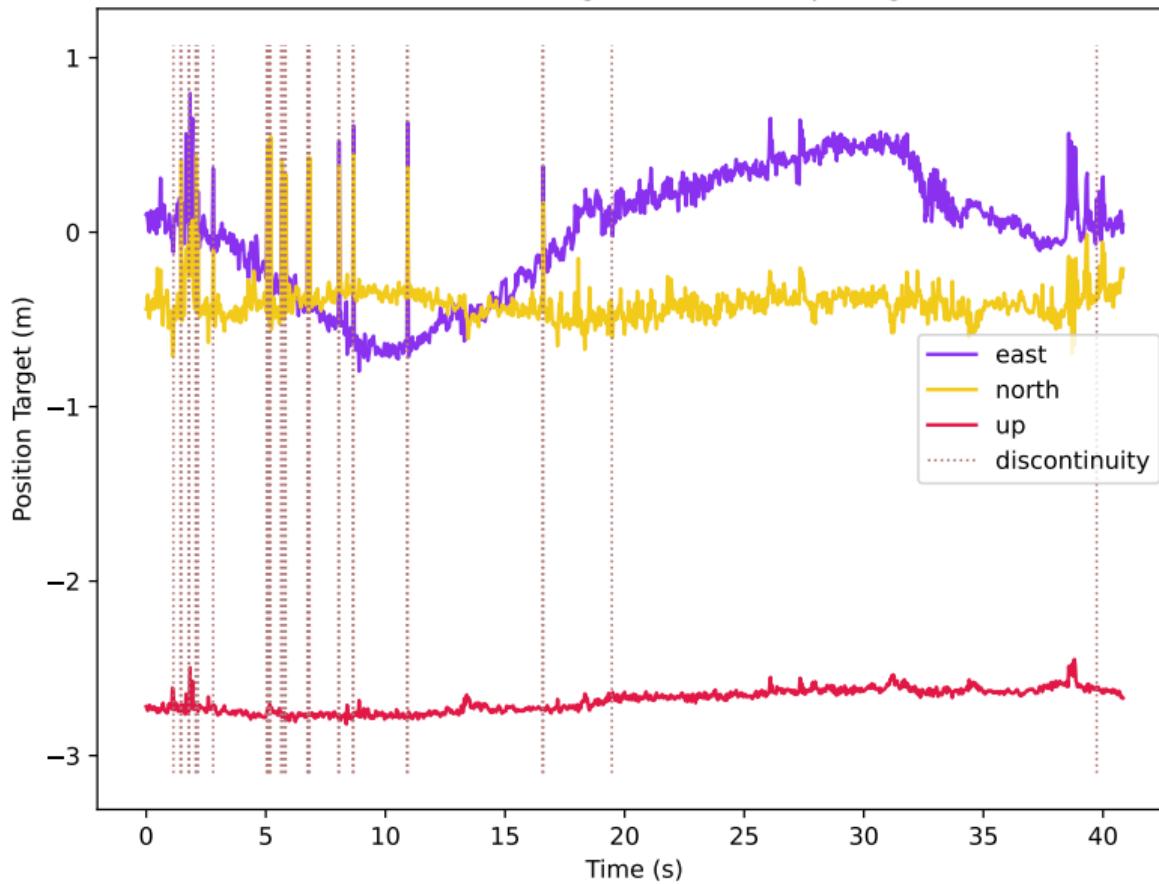


WhyCode Multi

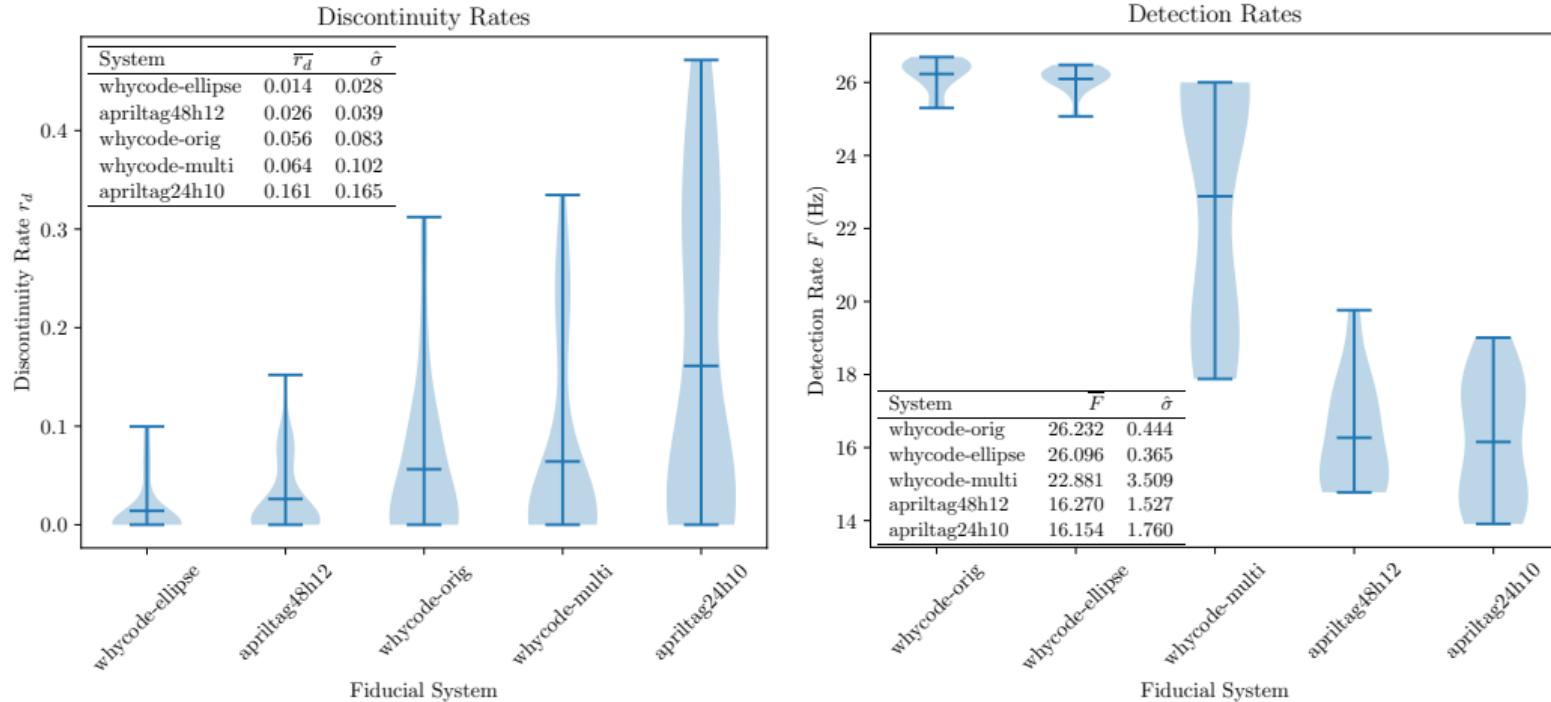


# Discontinuities

Test case: orbit-left-right-4, Marker: apriltag48h12



# Evaluation Results



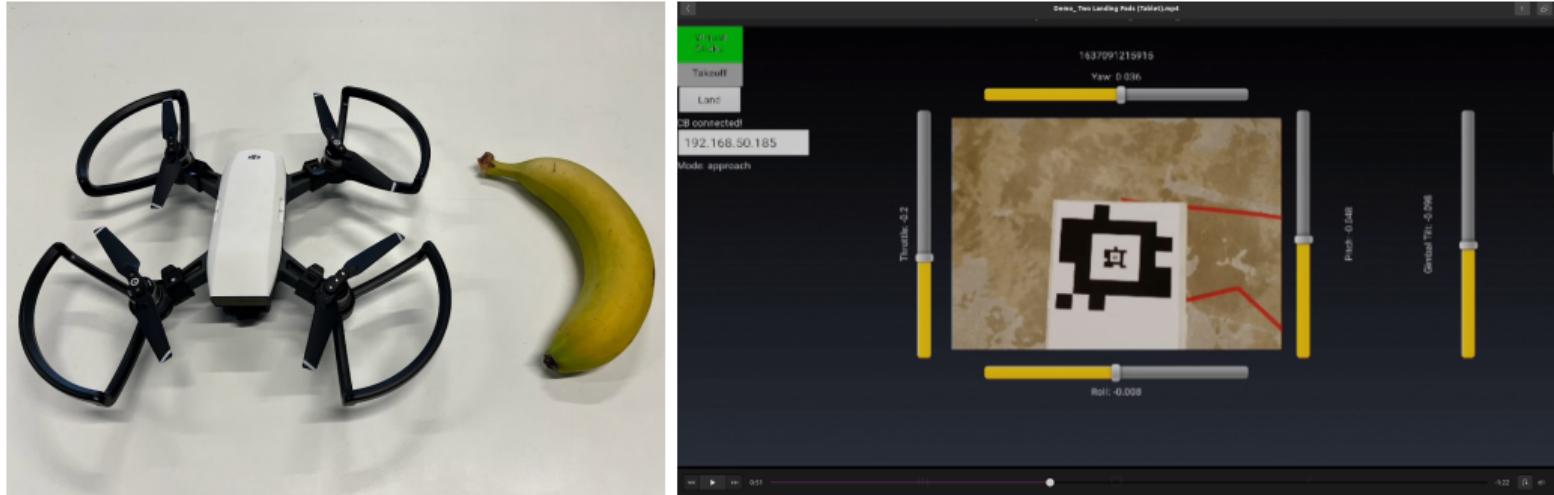
# Landing Pads with Fiducial Markers



**Figure 1:** Classic, downward-facing, fixed camera. Wubben et al. 2019

- ▶ Fixed, downward-facing camera paradigm
- ▶ Loses sight of the landing pad in adverse conditions (e.g. wind)

# Proof of Concept Landing with Actuated Camera



Demonstration Video

## Future Work: Fiducial Tests

- ▶ Re-conduct fiducial landing tests with actuated camera
- ▶ Raw pose data (same as before)
- ▶ Filtered pose data (KF, etc)
- ▶ Hybrid data
  - ▶ Position from marker
  - ▶ Orientation from camera gimbal



## Unstructured Case: Lava Flows

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# RAVEN, Mars Analog Missions in Iceland



# RAVEN, Mars Analog Missions in Iceland



# Lava Flow Landings



Manual Lava Landing Video

# Reykjavík University = No-Fly Zone



# Lava Flow Landing Data Collection Area: Stóra-Bolluhraun



Video

## Moving Forward

- ▶ Transform depth image using IMU
- ▶ Conventional signal processing techniques
- ▶ Possible: Deep learning (embedded TPU/GPU)
- ▶ Synthetic data generation using LIDAR point clouds: AirSim
- ▶ Analog<sup>2</sup> Missions

# Main Messages



- ▶ Topic: autonomous drone control – landing
- ▶ Methods:
  - ▶ Fiducial markers with camera actuation
  - ▶ Lava flow landings: terrain analysis with RGBD camera + IMU
  - ▶ Embedded processing only, no active ground infrastructure
- ▶ Are there any questions?