



Autonomous Multirotor Landing on Landing Pads and Lava Flows

Joshua Springer

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Reykjavik University

Department of Computer Science

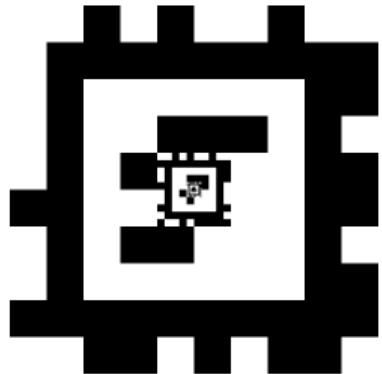
Supervisor: Marcel Kyas

Topic Overview

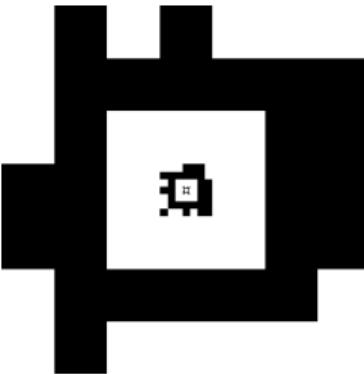
- ▶ Autonomous drone landing: hard, needs to be precise
- ▶ Often depends on GPS, blind to obstacles
- ▶ Often needs to be more precise than GPS (or GPS-denied)
- ▶ Landing pads: fiducial markers
- ▶ Terrain relative navigation
- ▶ Aesthetics:
 - ▶ Embedded processing only → efficient, quick, dedicated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

Progress So Far

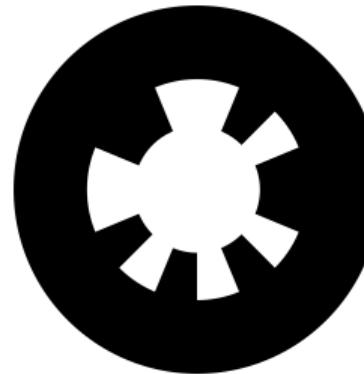
Fiducial Markers



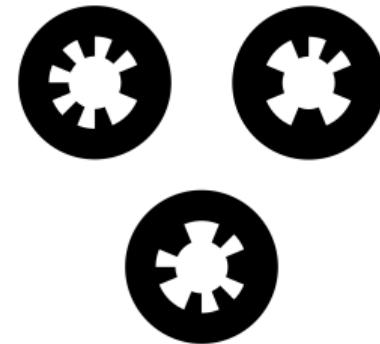
(a) April Tag 48h12 [2]



(b) April Tag 24h10 [1]

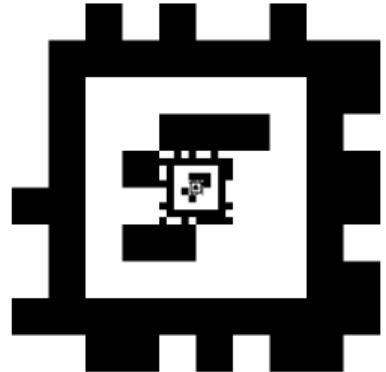


(c) WhyCode (Orig)[3]

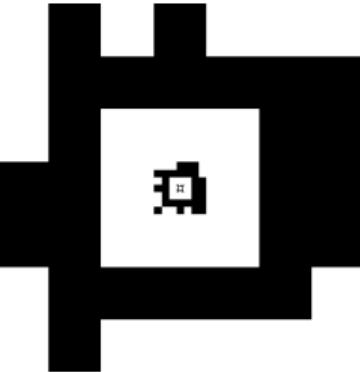


(d) WhyCode Multi [1]

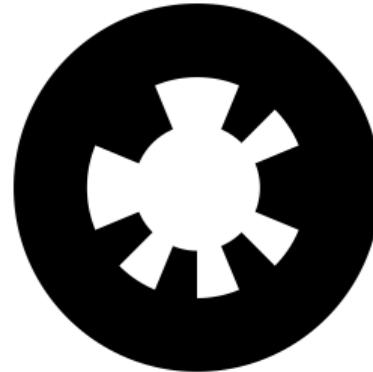
Fiducial Markers



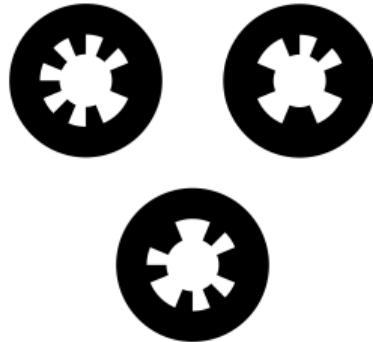
(a) April Tag 48h12 [2]



(b) April Tag 24h10 [1]



(c) WhyCode (Orig)[3]



(d) WhyCode Multi [1]

- ▶ Marker *position* → accurate
- ▶ Marker *orientation* → ambiguous

Landing Pads with Fiducial Markers

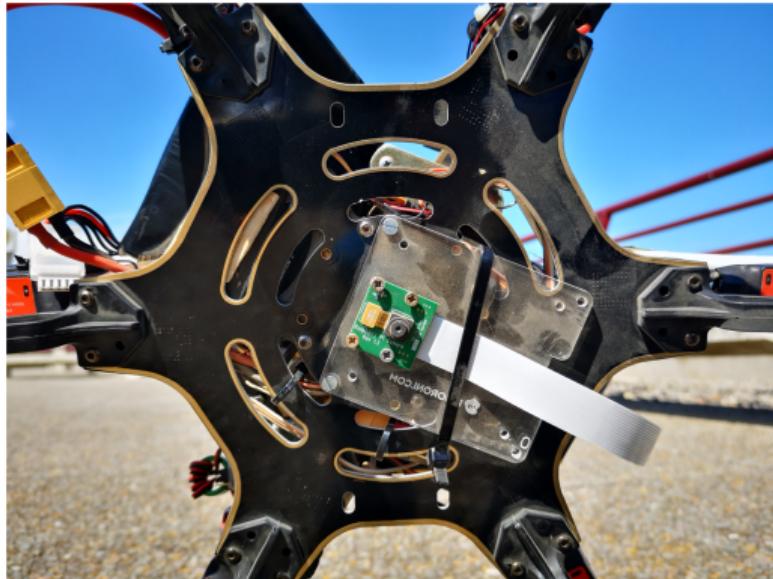
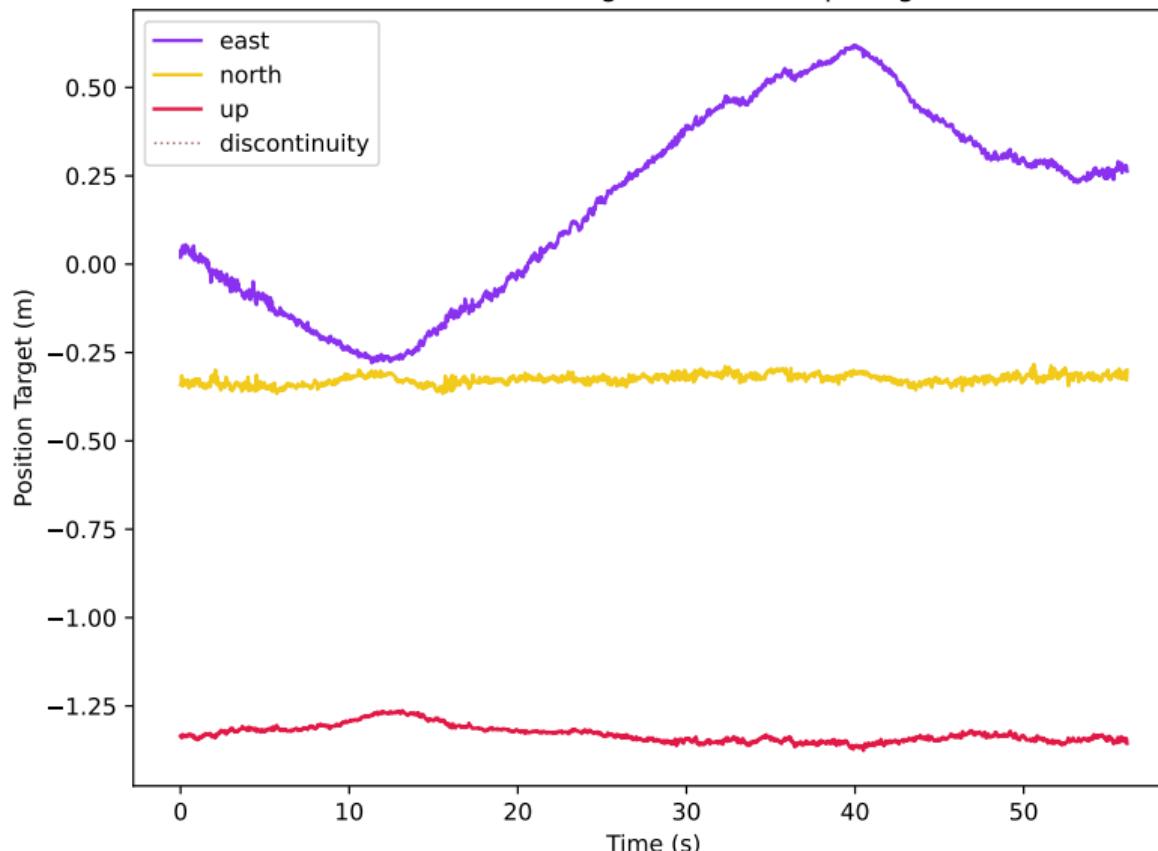


Figure 2: Classic, downward-facing, fixed camera. [4]

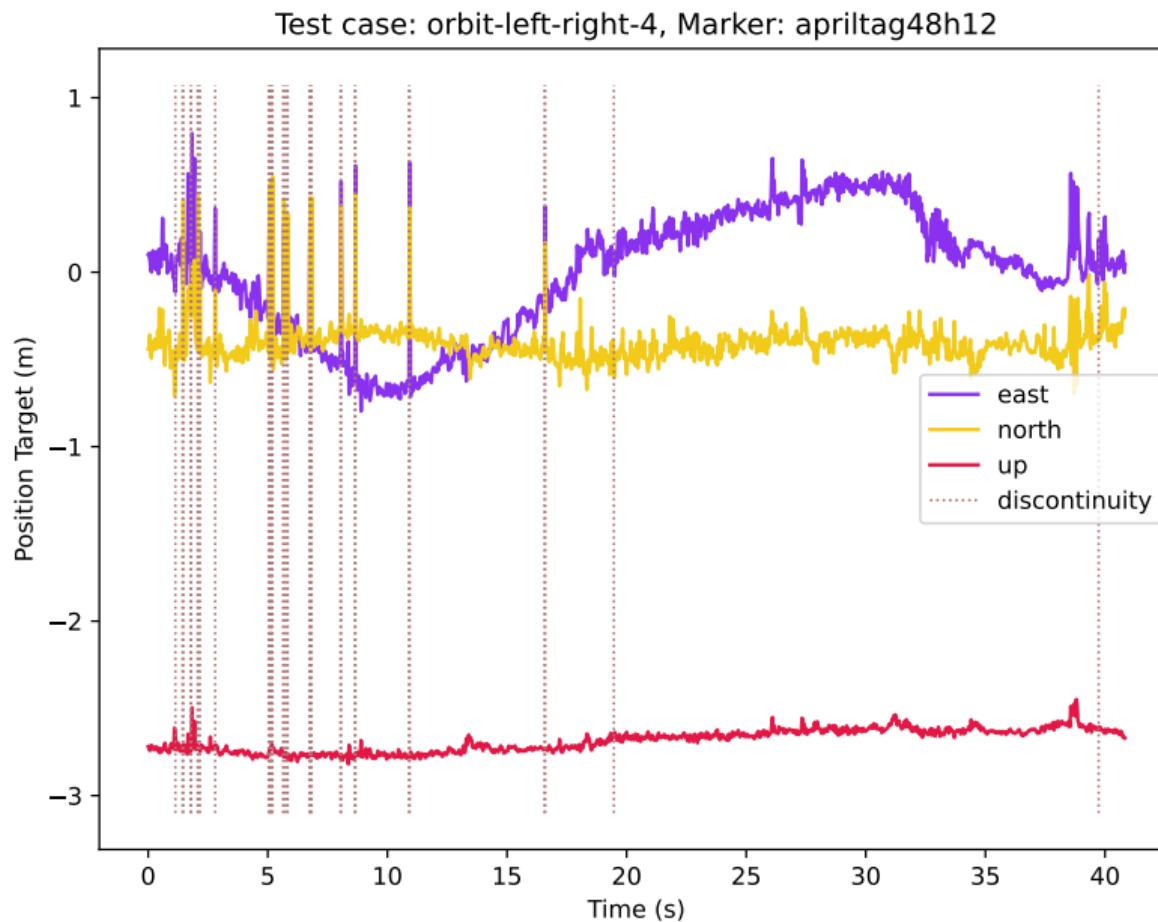
- ▶ Fixed, downward-facing camera paradigm
- ▶ Loses sight of the landing pad in adverse conditions (e.g. wind)

Example Test Case

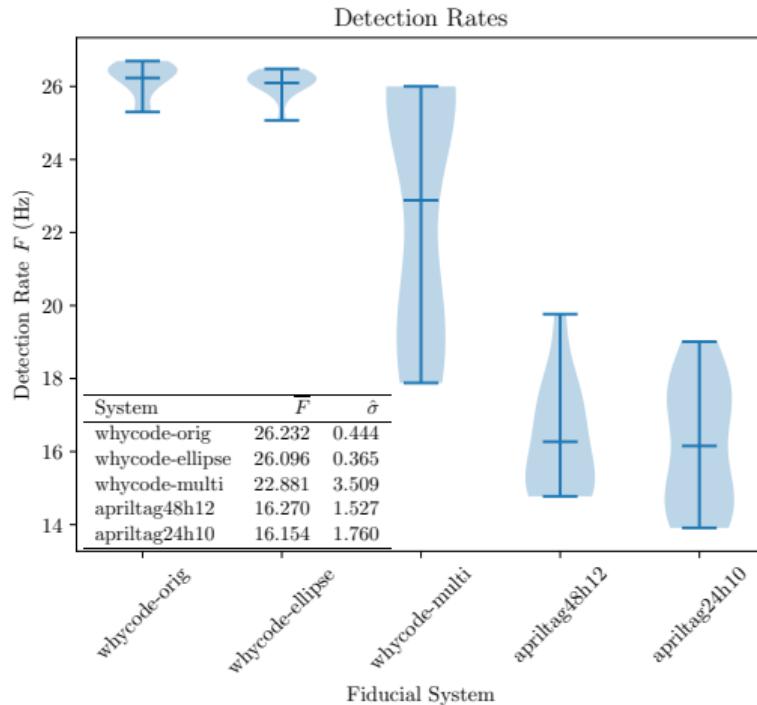
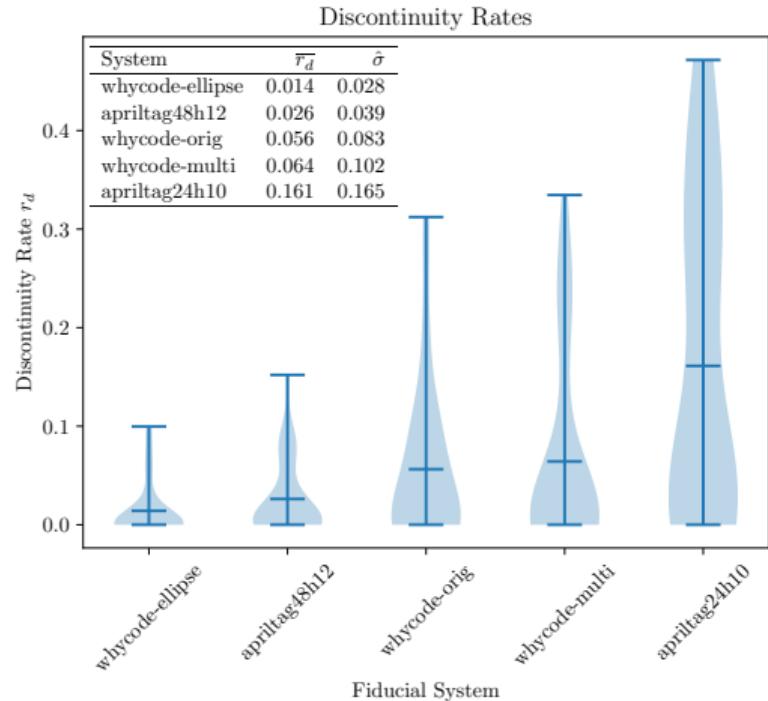
Test case: orbit-left-right-3, Marker: apriltag48h12



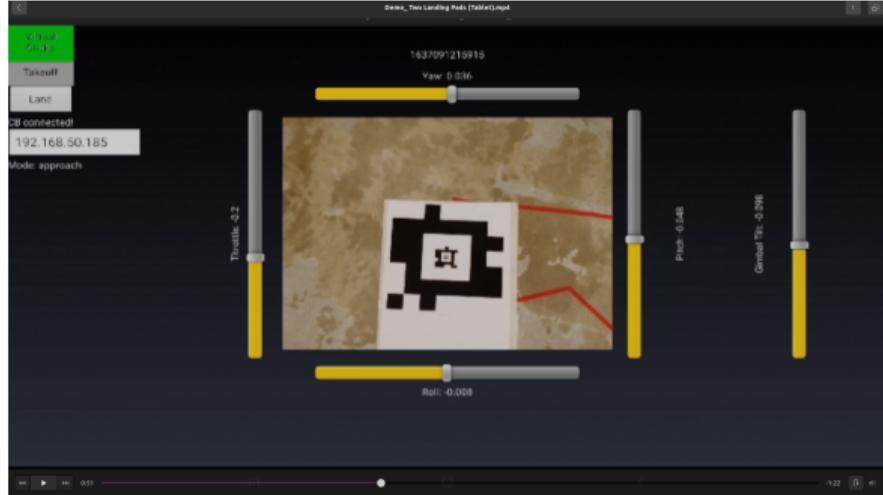
Example Test Case with Discontinuities



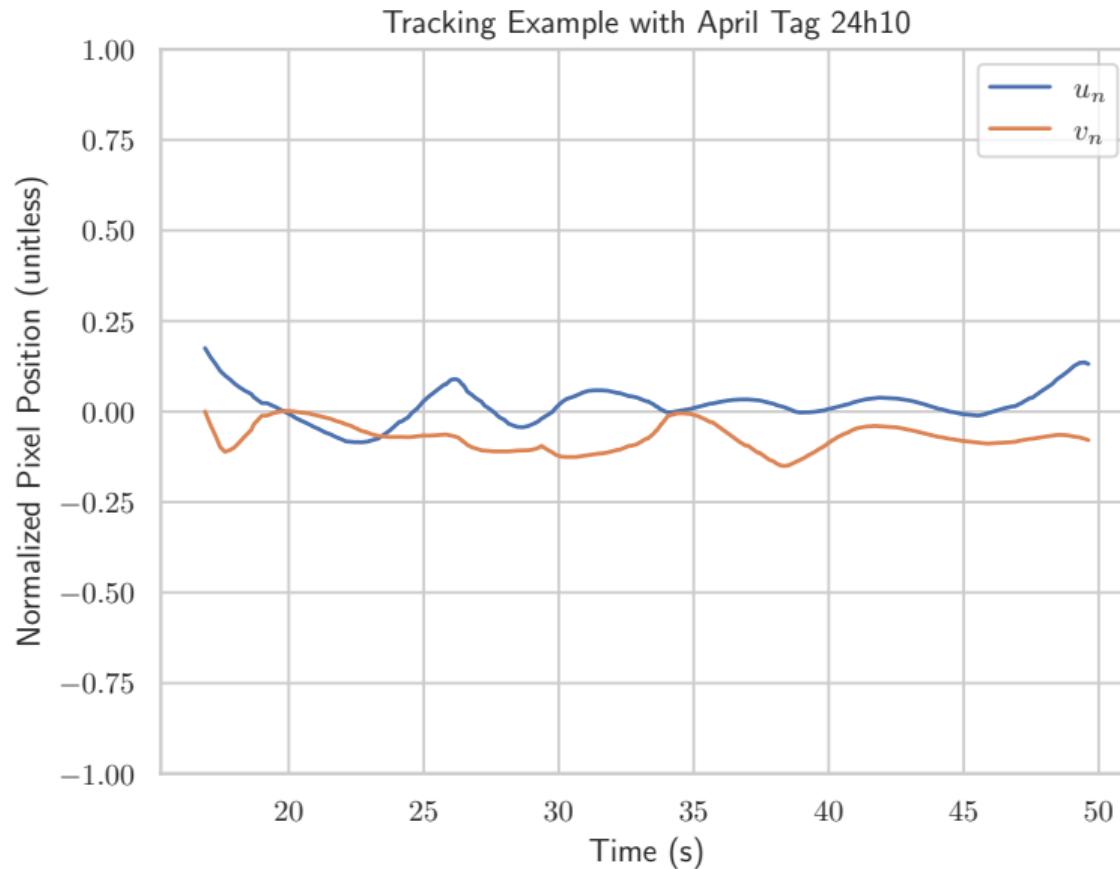
Results



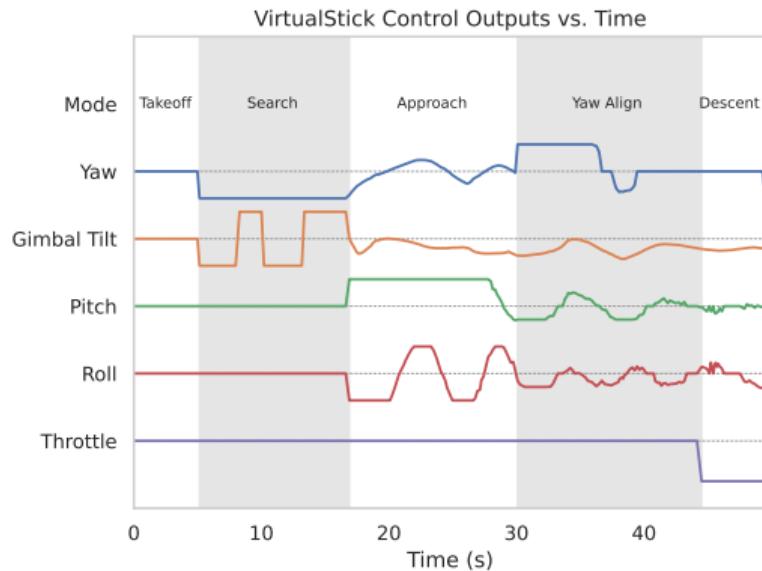
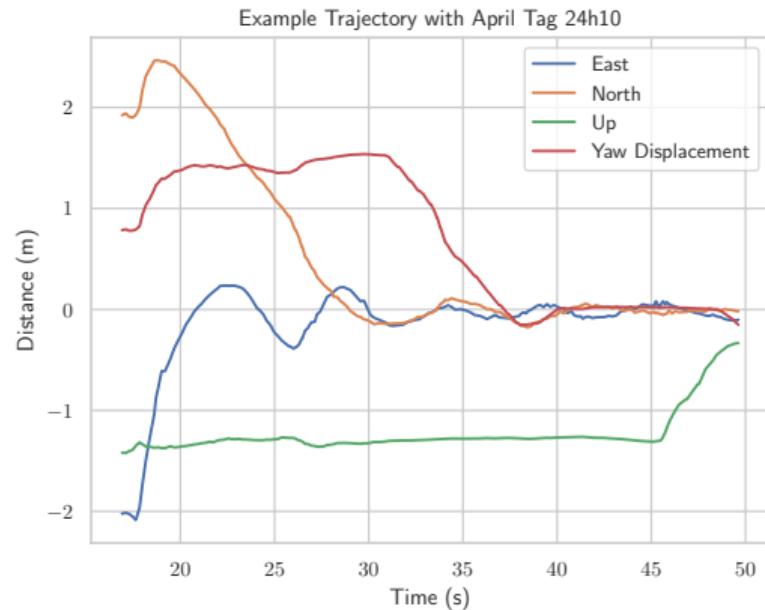
Proof of Concept Landing with Actuated Camera



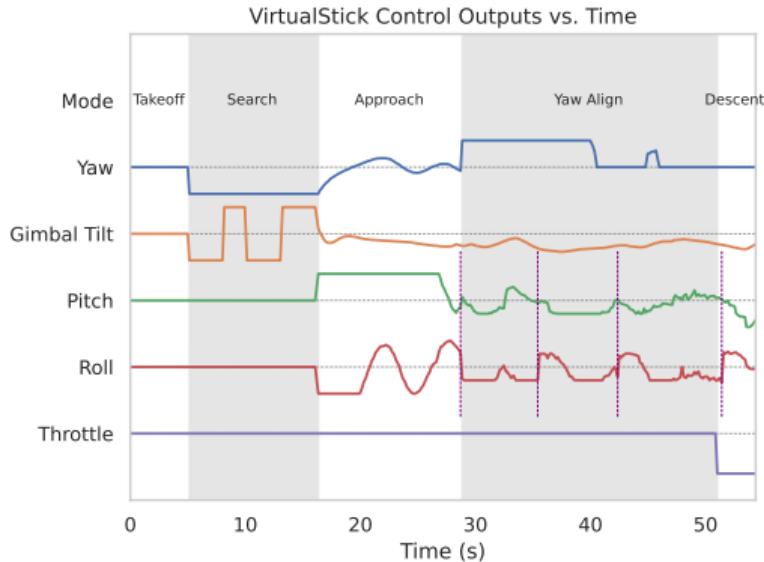
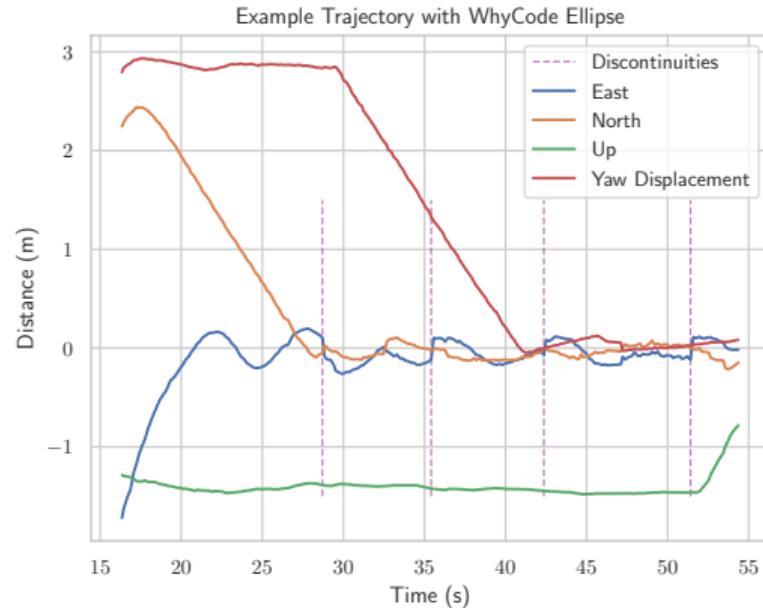
Tracking Performance Example



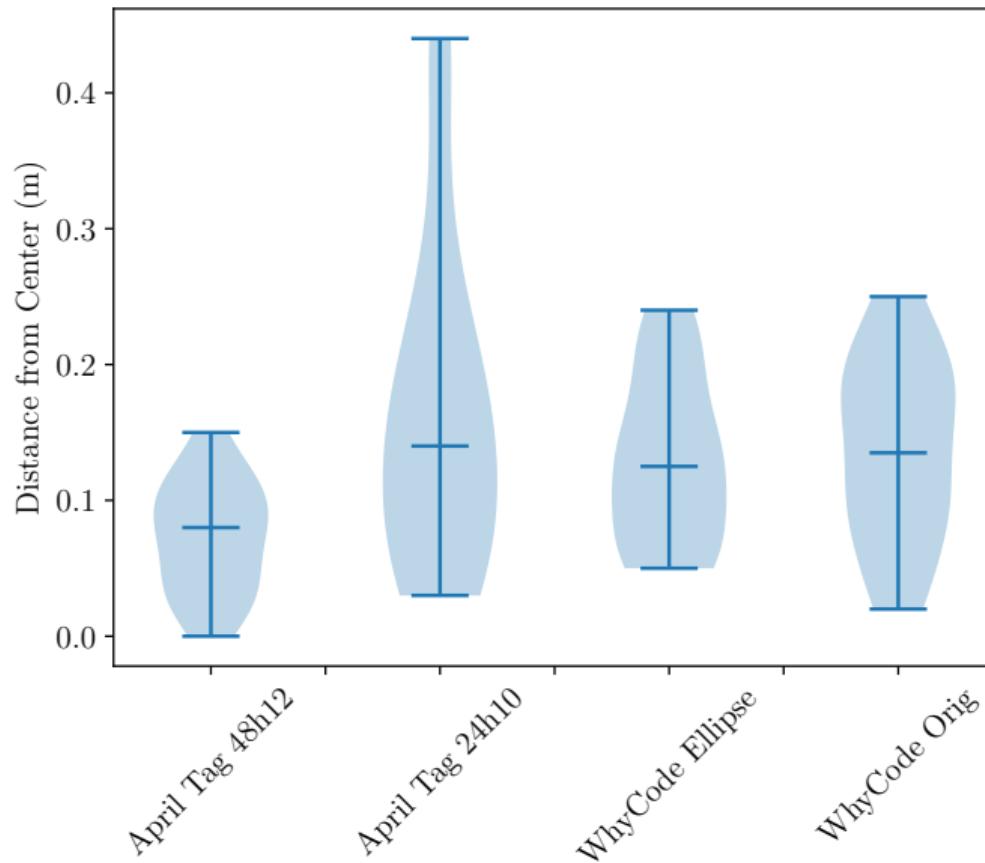
Trajectory and Control Signals



Trajectory and Control Signals (With Discontinuities)



Overall Performance



RAVEN, Mars Analog Missions in Iceland



Lava Flow Landings



Moving Forward

More Fiducial Tests

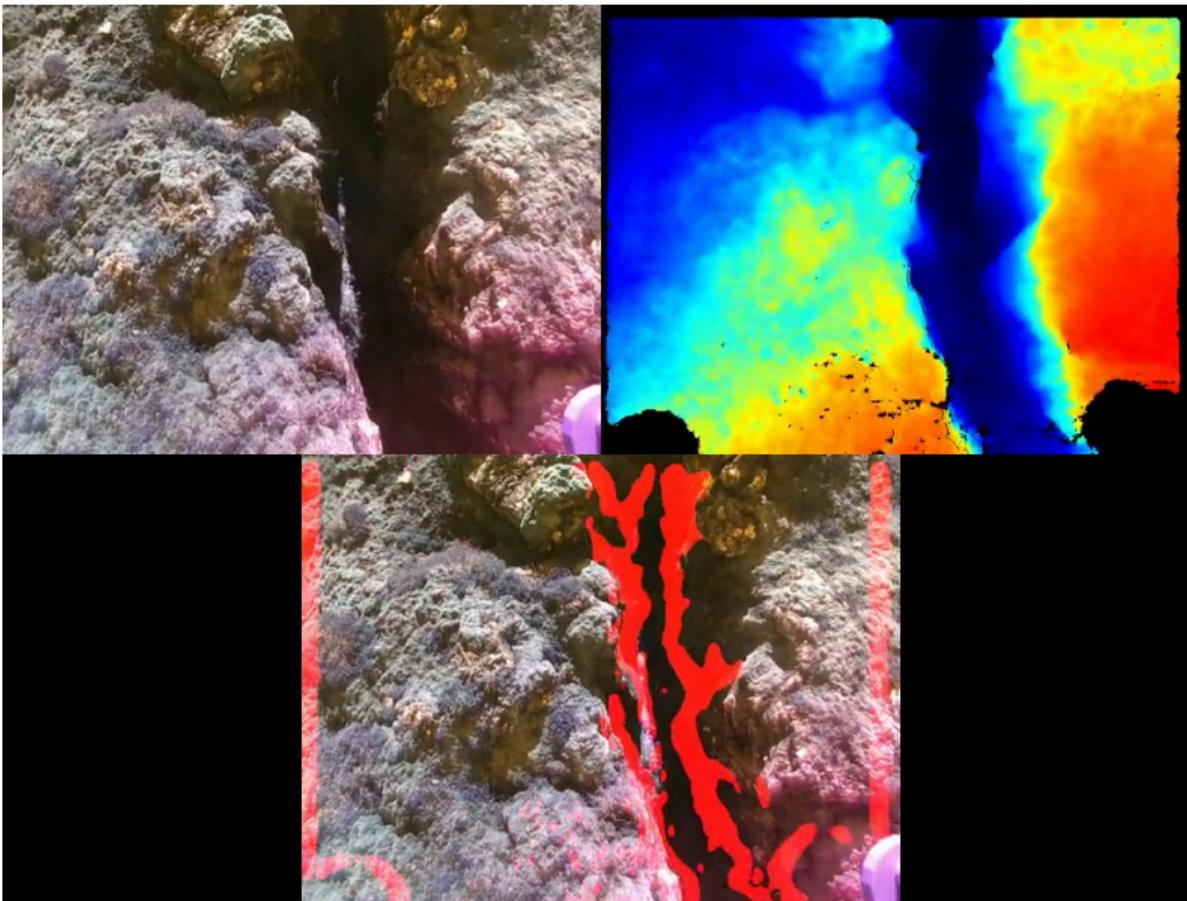
- ▶ Re-conduct fiducial landing tests with actuated camera
- ▶ Raw pose data (same as before)
- ▶ Filtered pose data (KF, etc)
- ▶ Hybrid data
 - ▶ Position from marker
 - ▶ Orientation from camera gimbal



Lava Flow Landing: Stóra-Bolluhraun



Example Depth Image Processing



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?

References

- ▶ Joshua Springer and Marcel Kyas.
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- ▶ M. Krogius, A. Haggenmiller, and E. Olson.
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- ▶ Peter Lightbody, Tomáš Krajník, and Marc Hanheide.
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In *Proceedings of the Symposium on Applied Computing*, SAC '17, pages 276–282, New York, NY, USA, 2017. ACM.
- ▶ Jamie Wubben, Francisco Fabra, Carlos Calafate, Tomasz Krzeszowski, Johann Marquez-Barja, Juan-Carlos Cano, and Pietro Manzoni.
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