



Autonomous Multirotor Landing on Landing Pads and Lava Flows

Joshua Springer

30 November 2022

Reykjavik University

Department of Computer Science

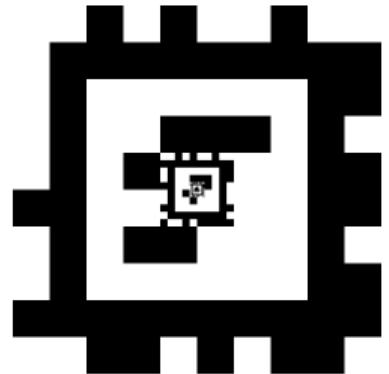
Supervisor: Marcel Kyas

Topic Overview

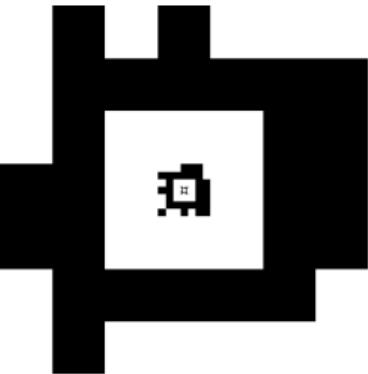
- ▶ Autonomous drone landing: hard, needs to be precise
- ▶ Often depends on GPS, blind to obstacles
- ▶ Often needs to be more precise than GPS (or GPS-denied)
- ▶ Landing pads: fiducial markers
- ▶ Terrain relative navigation
- ▶ Aesthetics:
 - ▶ Embedded processing only → efficient, quick, dedicated 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

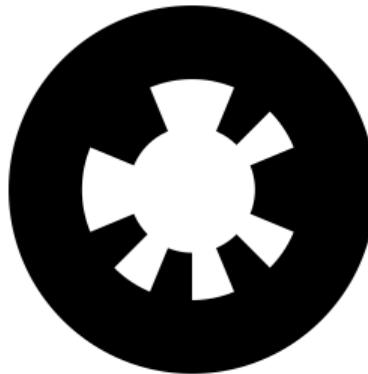
Fiducial Markers



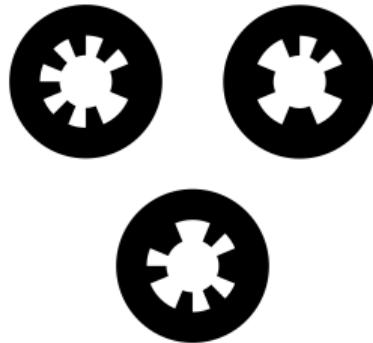
(a) April Tag 48h12 [2]



(b) April Tag 24h10 [1]

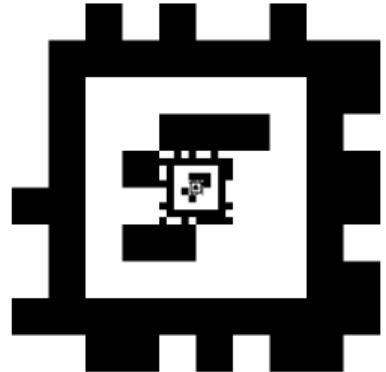


(c) WhyCode (Orig)[3]

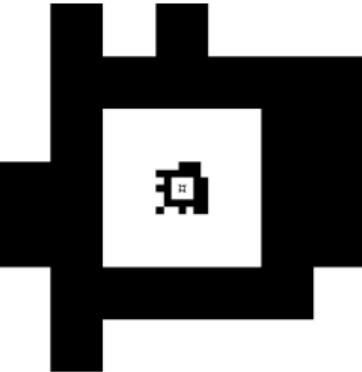


(d) WhyCode Multi [1]

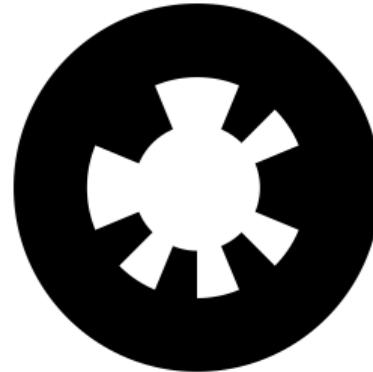
Fiducial Markers



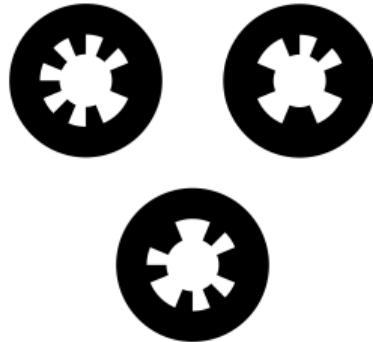
(a) April Tag 48h12 [2]



(b) April Tag 24h10 [1]



(c) WhyCode (Orig)[3]



(d) WhyCode Multi [1]

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

Landing Pads with Fiducial Markers

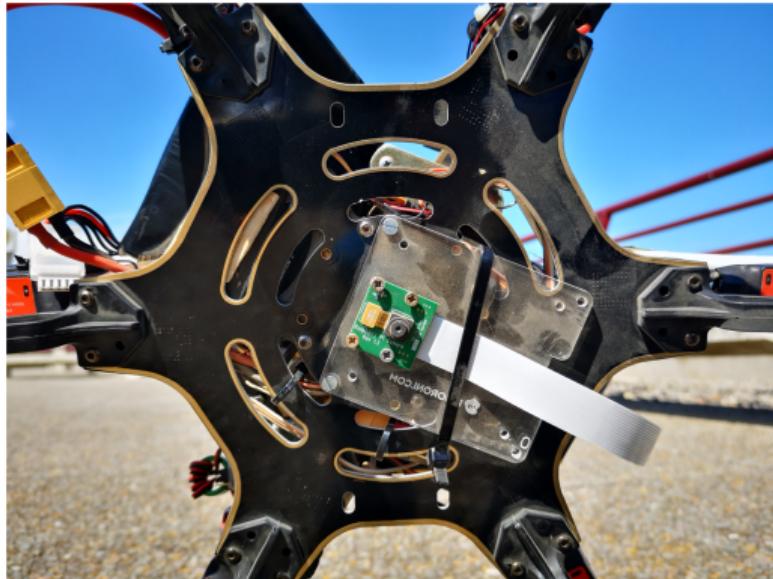
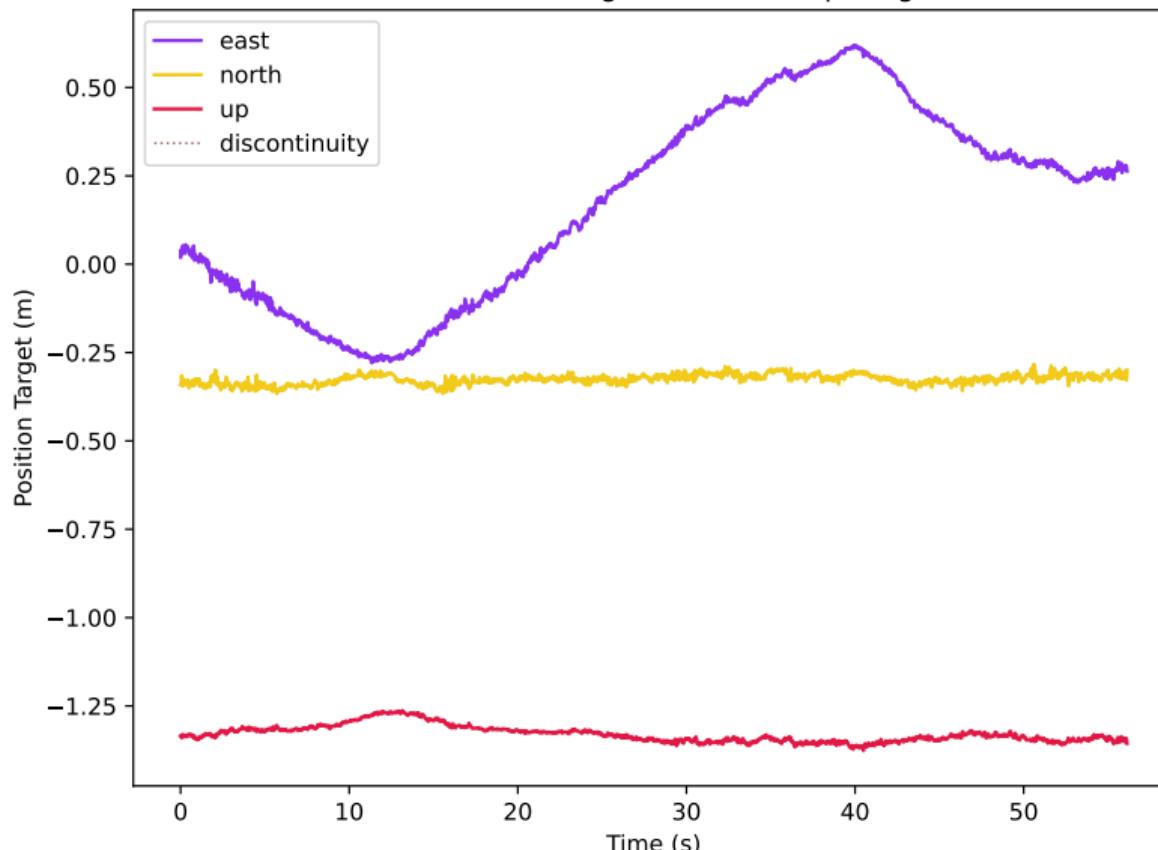


Figure 2: Classic, downward-facing, fixed camera. [4]

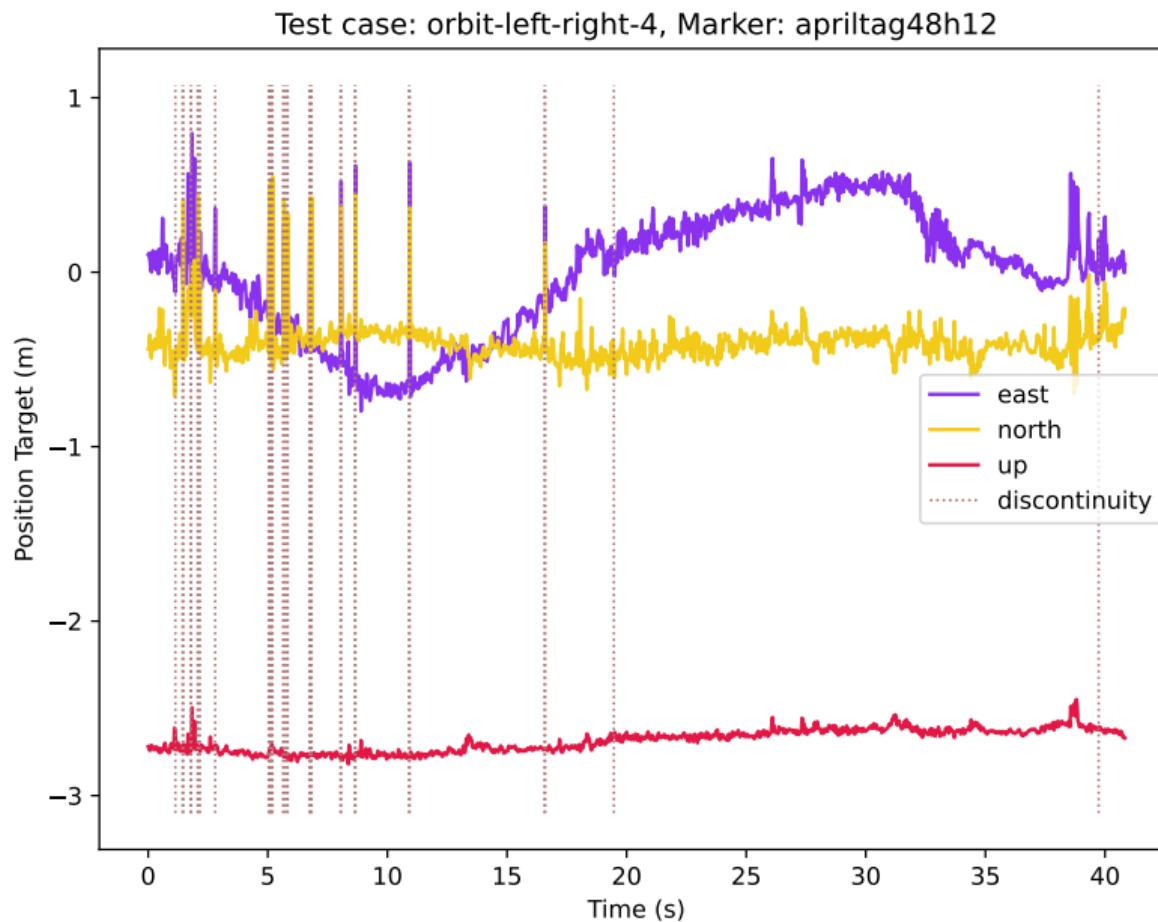
- ▶ Fixed, downward-facing camera paradigm
- ▶ Loses sight of the landing pad in adverse conditions (e.g. wind)

Example Test Case

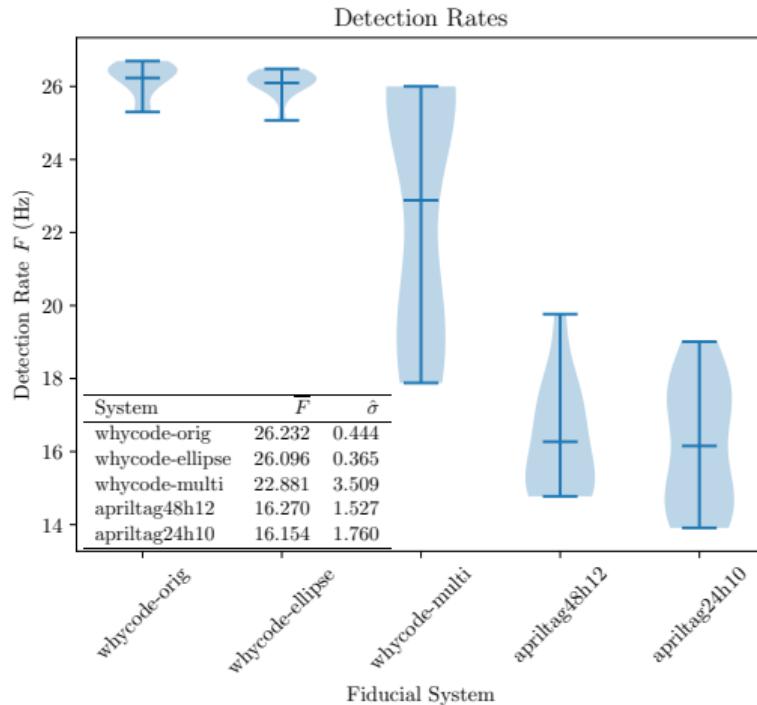
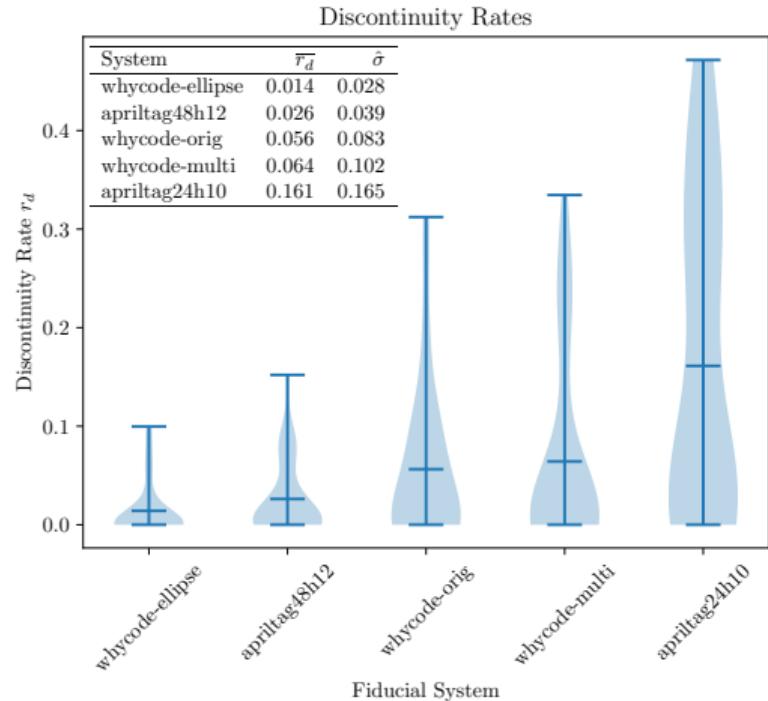
Test case: orbit-left-right-3, Marker: apriltag48h12



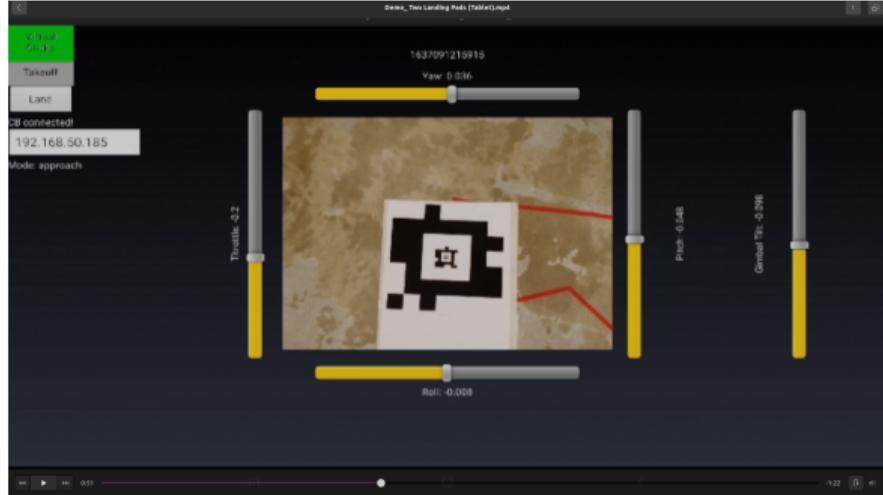
Example Test Case with Discontinuities



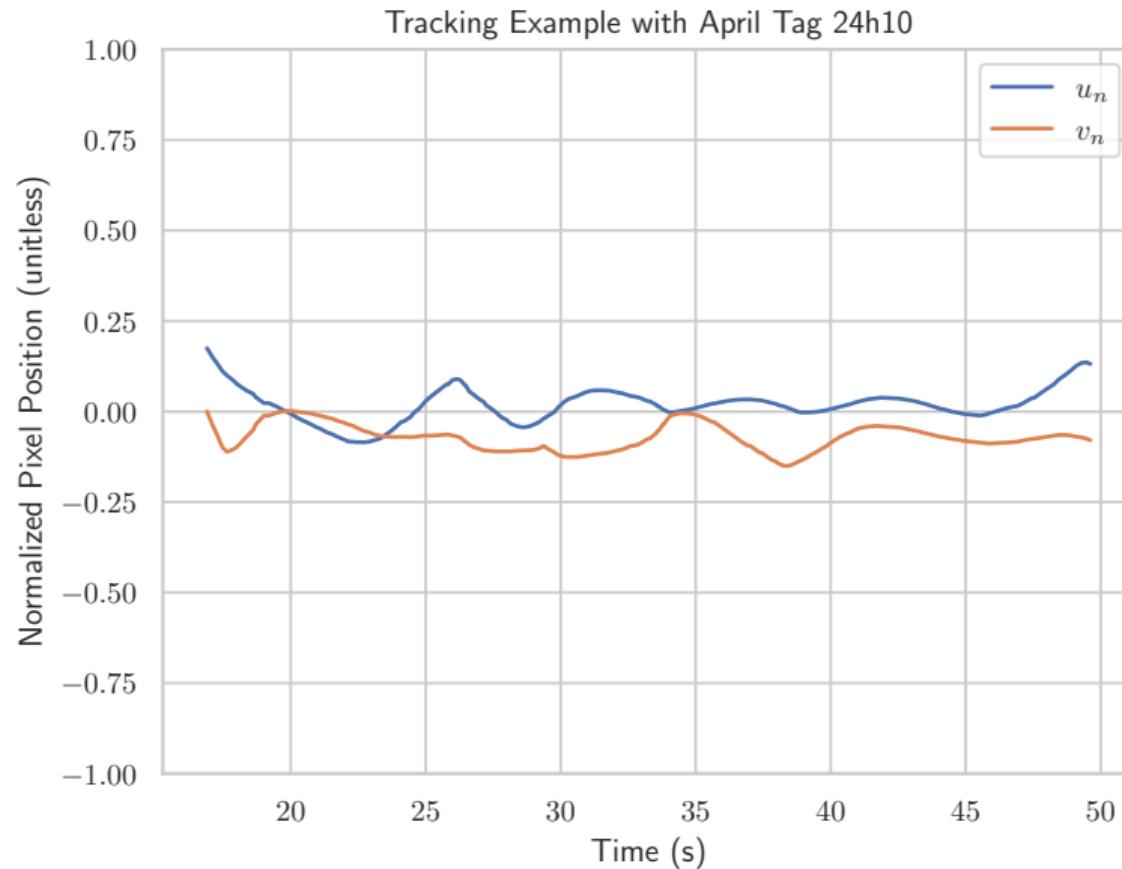
Results



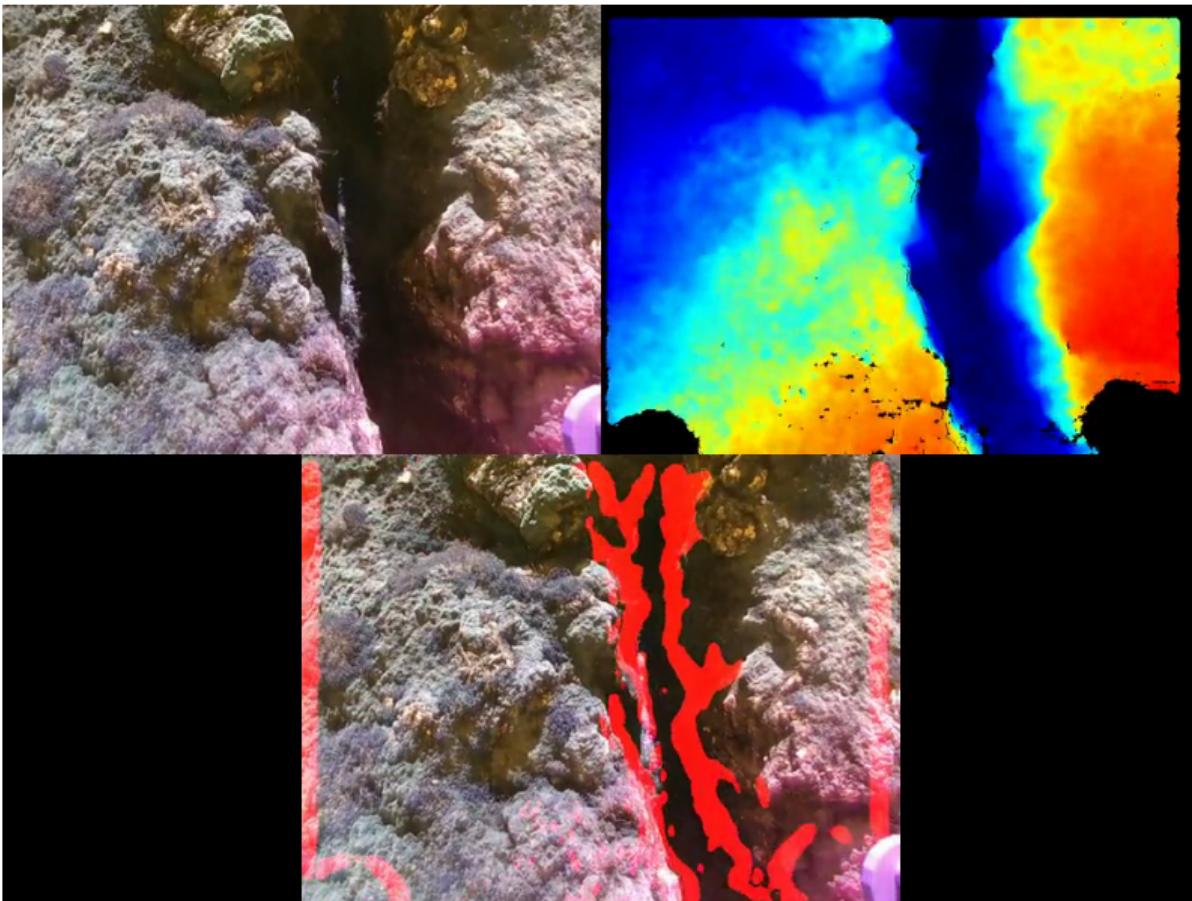
Proof of Concept Landing with Actuated Camera



Tracking Performance Example



Example Depth Image Processing



References

- ▶ Joshua Springer and Marcel Kyas.
Evaluation of Orientation Ambiguity and Detection Rate in April Tag and WhyCode.
In *2022 IEEE International Conference on Robotic Computing*, December 2022.
- ▶ M. Krogius, A. Haggenmiller, and E. Olson.
Flexible layouts for fiducial tags.
In *2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pages 1898–1903, 2019.
- ▶ Peter Lightbody, Tomáš Krajník, and Marc Hanheide.
A Versatile High-performance Visual Fiducial Marker Detection System with Scalable Identity Encoding.
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.
Accurate Landing of Unmanned Aerial Vehicles Using Ground Pattern Recognition.
Electronics, 8:1532, 12 2019.