



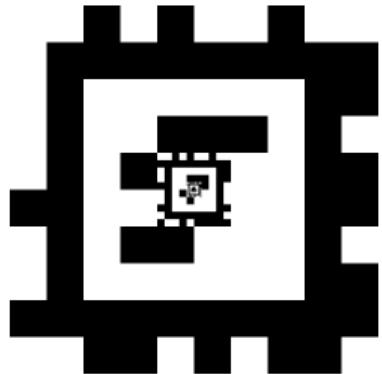
Autonomous Drone Landing with Fiducial Markers and a Gimbal-Mounted Camera for Active Tracking

Joshua Springer, Marcel Kyas

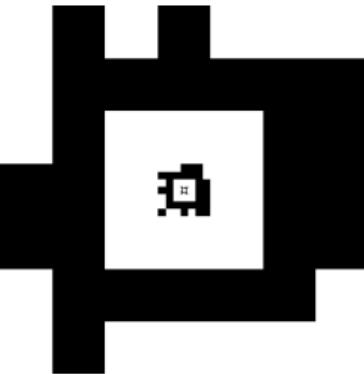
28 November 2022

Reykjavik University
Department of Computer Science

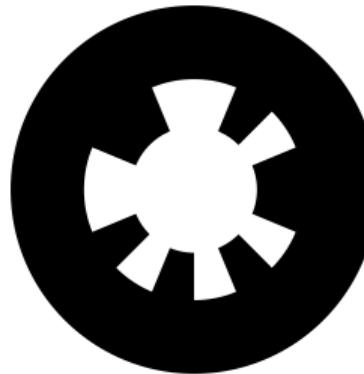
Fiducial Markers



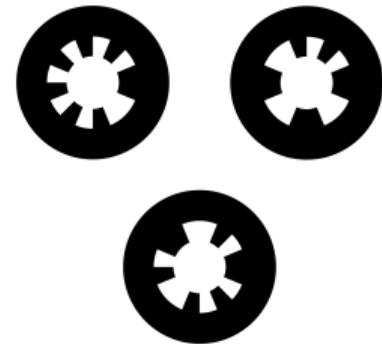
(a) April Tag 48h12 [4]



(b) April Tag 24h10 [3]

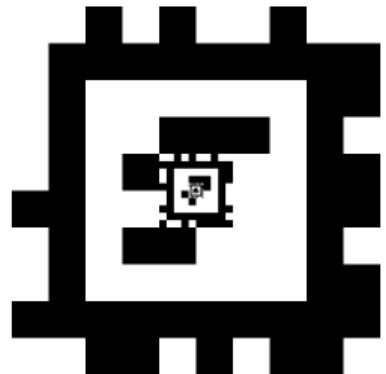


(c) WhyCode (Orig)[5]

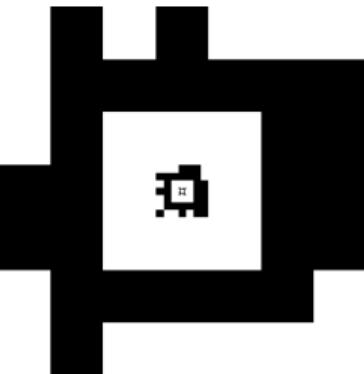


(d) WhyCode Multi [3]

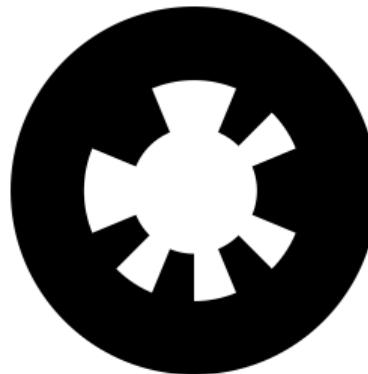
Fiducial Markers



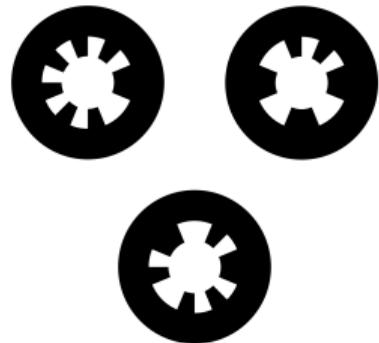
(a) April Tag 48h12 [4]



(b) April Tag 24h10 [3]



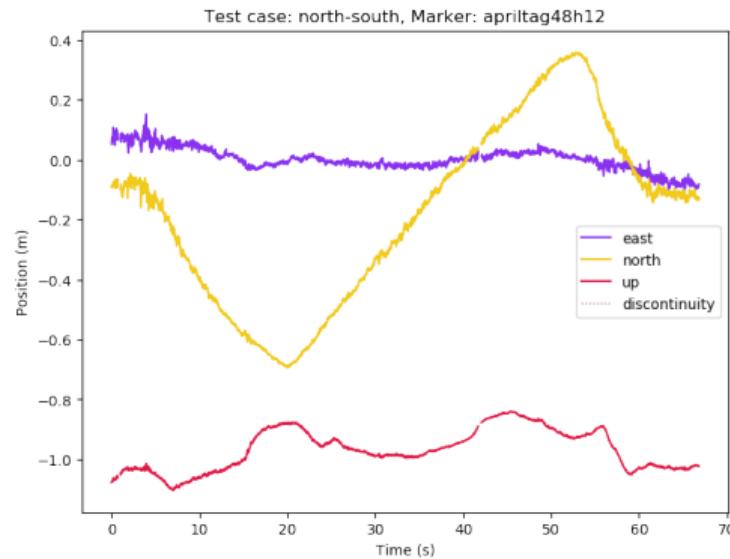
(c) WhyCode (Orig)[5]



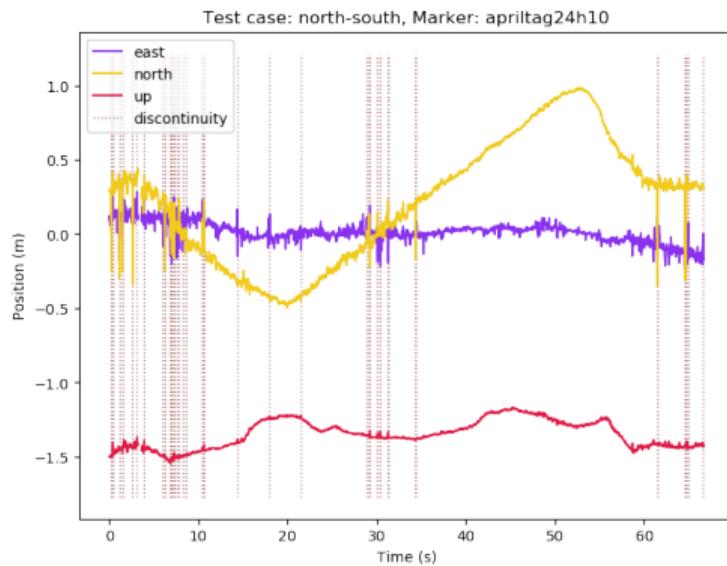
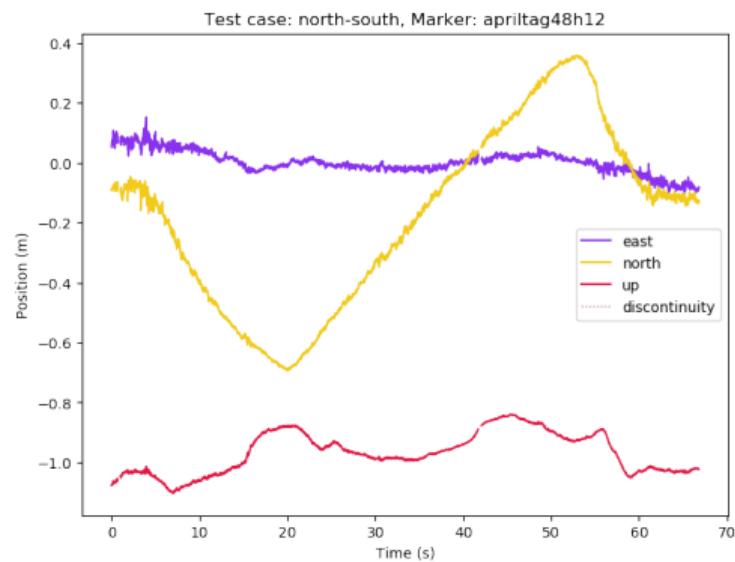
(d) WhyCode Multi [3]

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

Orientation Ambiguity



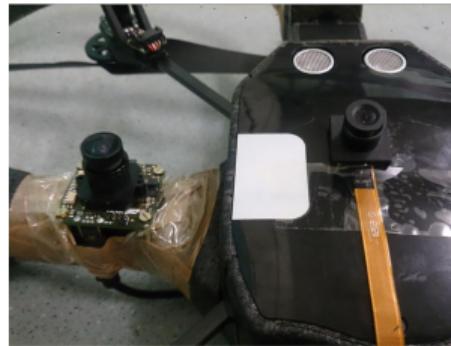
Orientation Ambiguity



The Downward-facing Camera Paradigm



(a) Single fixed camera. [6]



(b) Dual fixed cameras. [1]



(c) Gimbal/fixed cameras. [2]

- We want to leverage the standard monocular, gimbal-mounted camera.

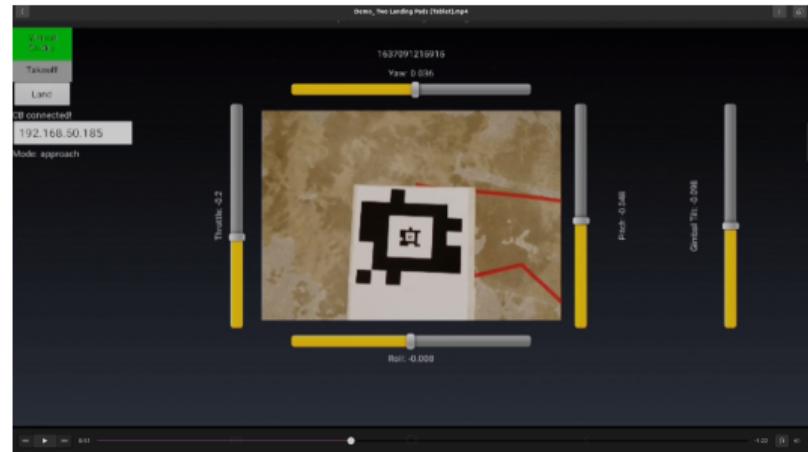
Testing Platform: DJI Spark

- ▶ Small quadcopter
- ▶ Gimbal-mounted camera
- ▶ DJI Mobile SDK

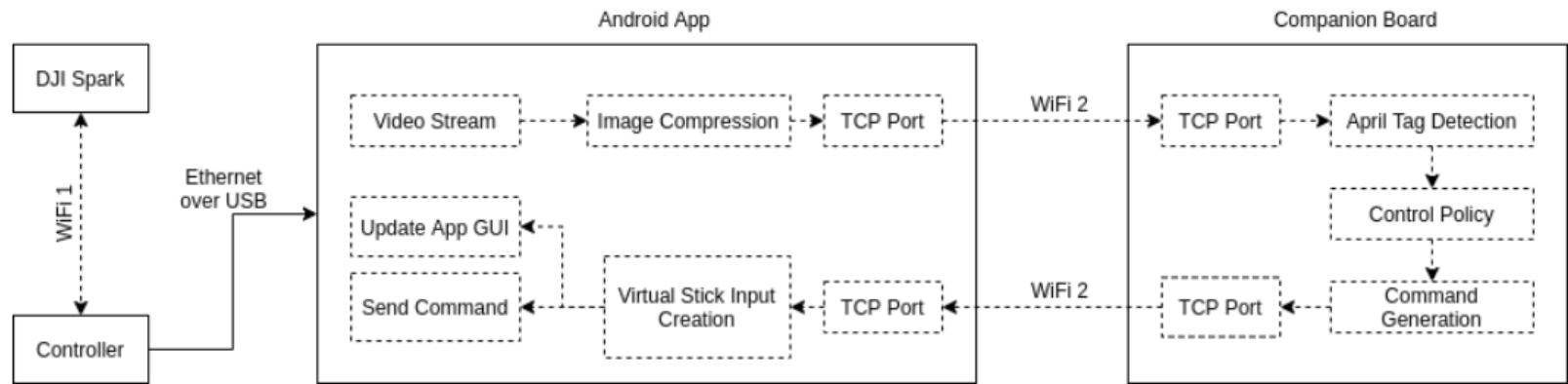


Testing Platform: Software Side

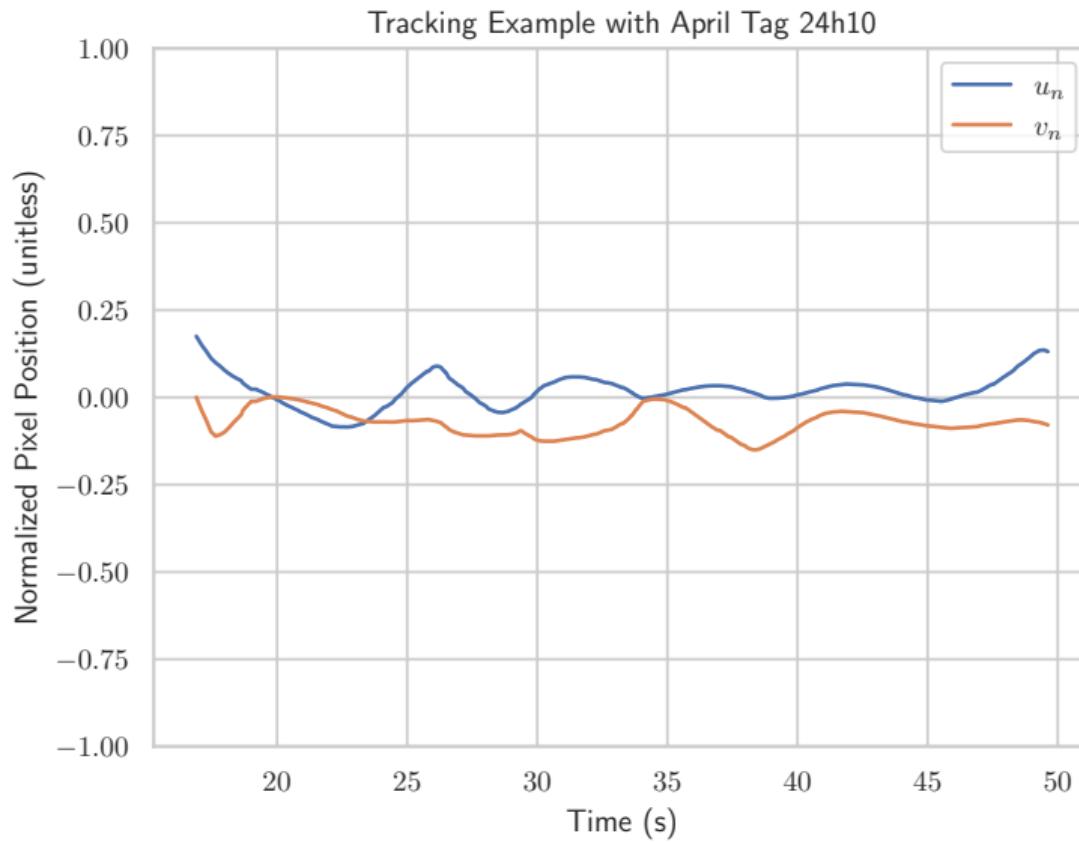
- ▶ DJI Mobile SDK: App-style architecture
- ▶ Export video to Raspberry Pi 4 companion board
- ▶ Return control signals



Data Flow

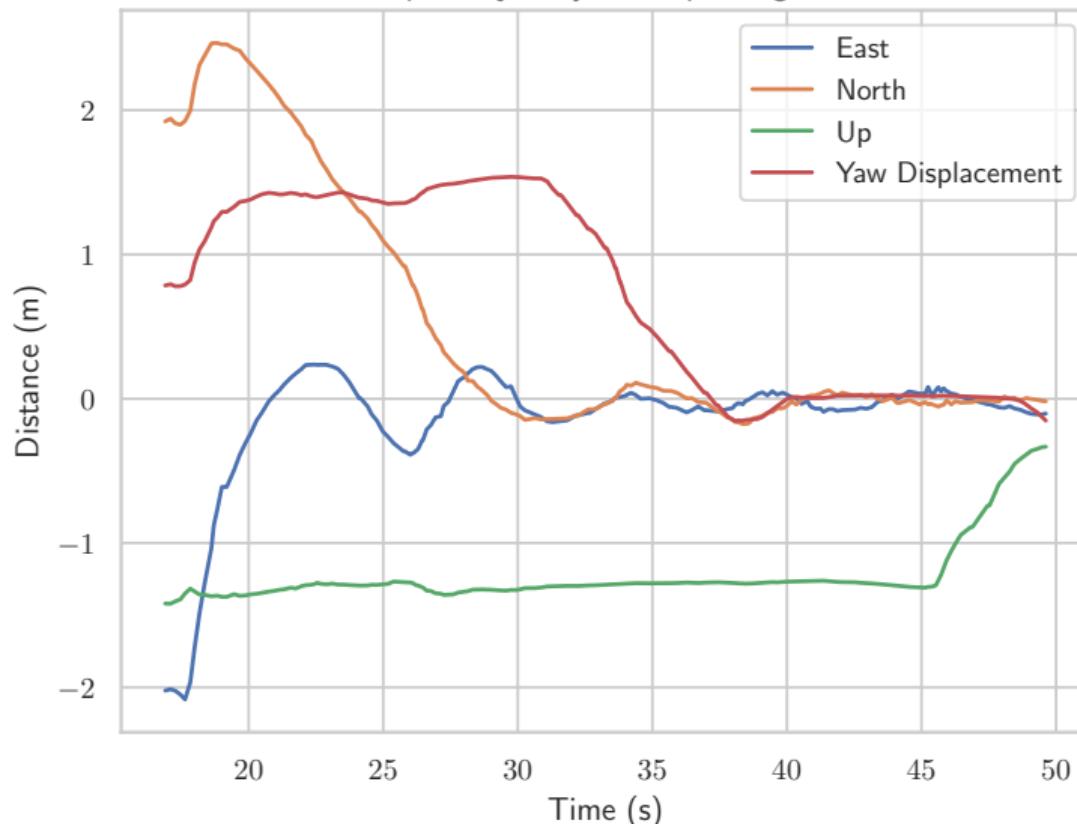


Example Tracking Performance

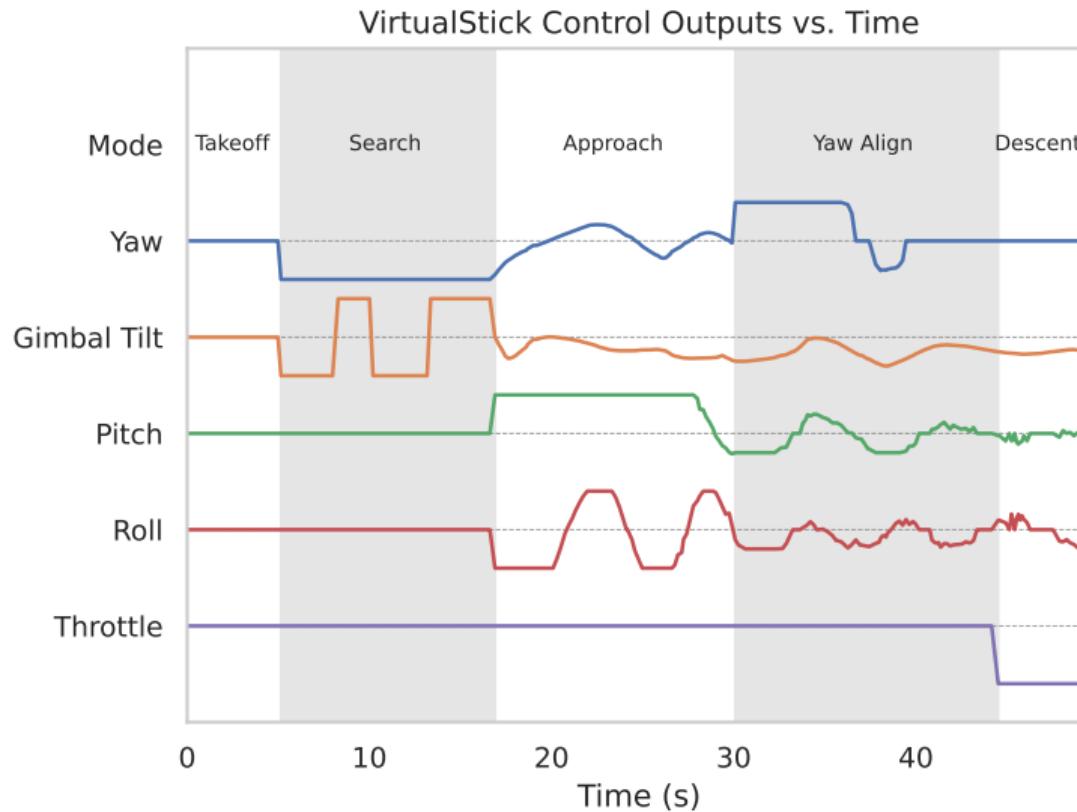


Example Landing Trajectory

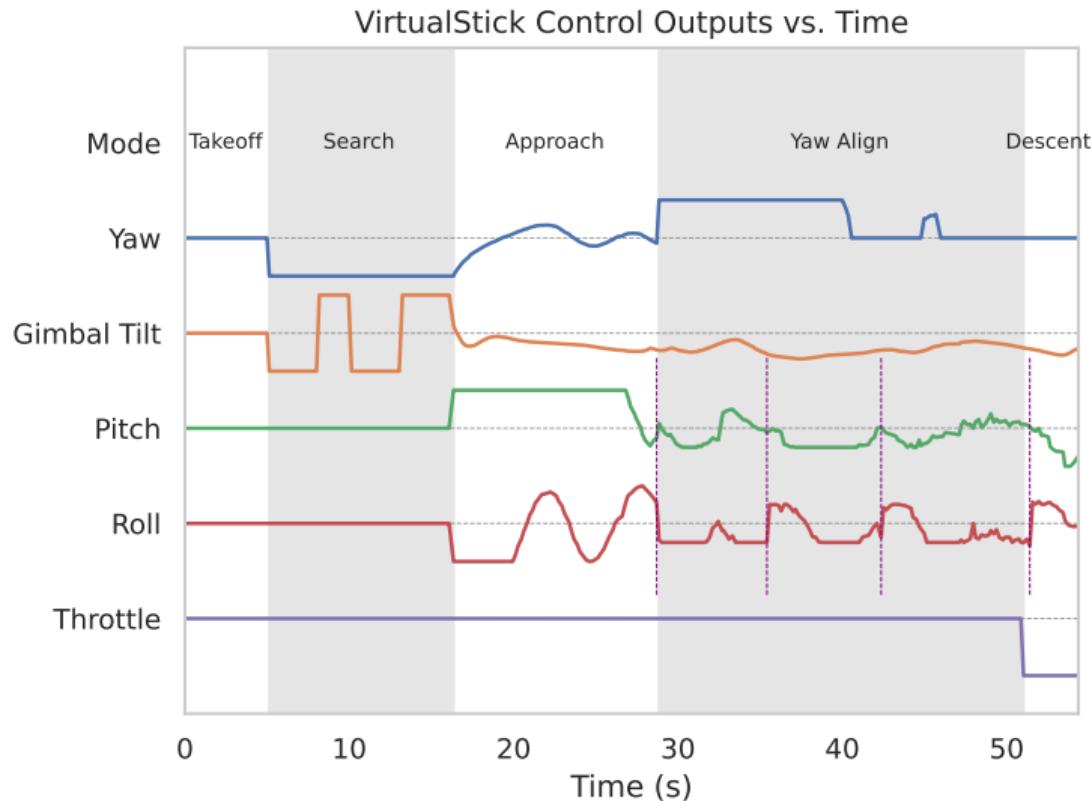
Example Trajectory with April Tag 24h10



Example Control Outputs

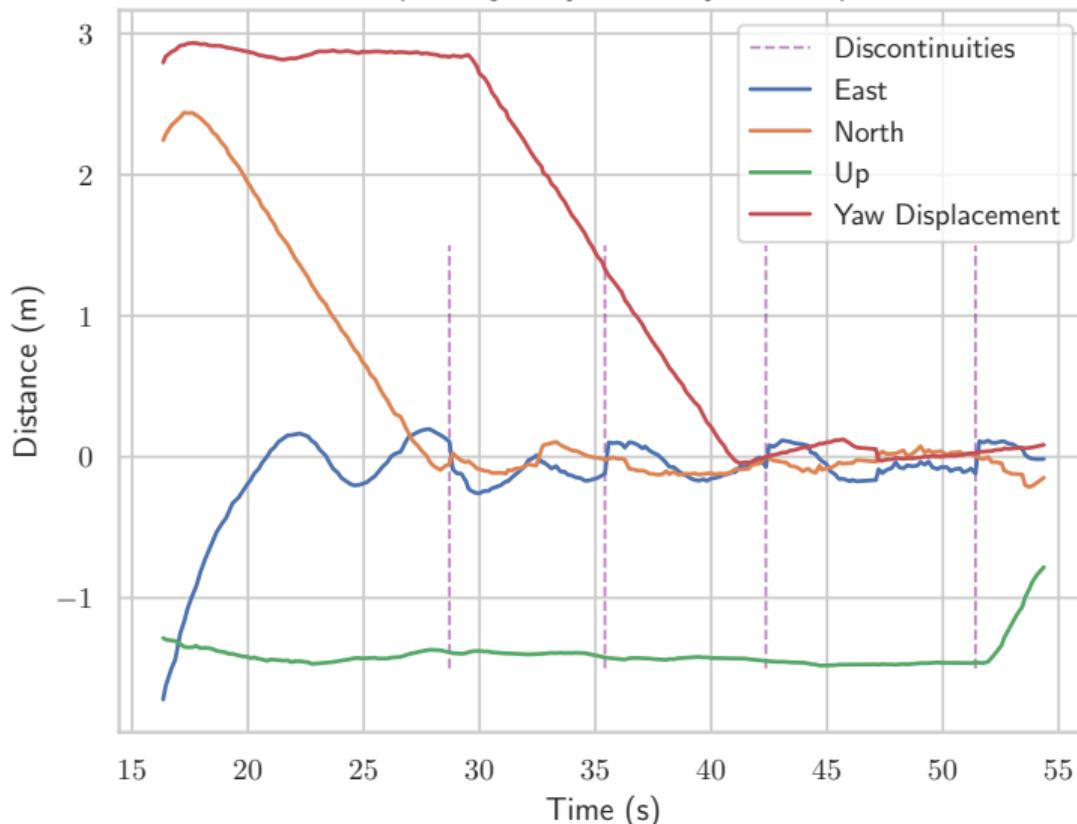


Control Outputs With Discontinuities

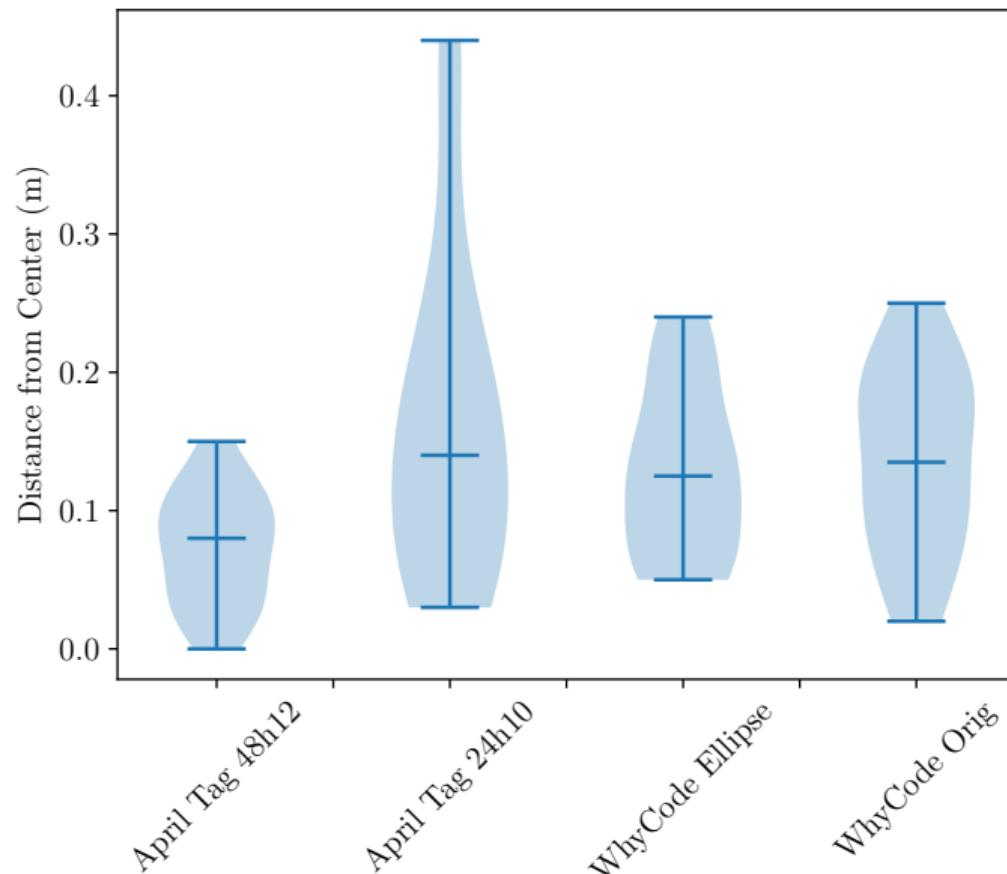


Landing Trajectory with Discontinuities

Example Trajectory with WhyCode Ellipse



Landing Radii



Future Work

- ▶ Use another drone platform

Future Work

- ▶ Use another drone platform
 - ▶ Phantom, Mavic, custom Tarot platform

Future Work

- ▶ Use another drone platform
 - ▶ Phantom, Mavic, custom Tarot platform
 - ▶ More gimbal tilt range

Future Work

- ▶ Use another drone platform
 - ▶ Phantom, Mavic, custom Tarot platform
 - ▶ More gimbal tilt range
- ▶ Connect companion board directly to controller

Future Work

- ▶ Use another drone platform
 - ▶ Phantom, Mavic, custom Tarot platform
 - ▶ More gimbal tilt range
- ▶ Connect companion board directly to controller
- ▶ Test 3 separate methods for each fiducial system:

Future Work

- ▶ Use another drone platform
 - ▶ Phantom, Mavic, custom Tarot platform
 - ▶ More gimbal tilt range
- ▶ Connect companion board directly to controller
- ▶ Test 3 separate methods for each fiducial system:
 - ▶ Raw/unfiltered marker pose

Future Work

- ▶ Use another drone platform
 - ▶ Phantom, Mavic, custom Tarot platform
 - ▶ More gimbal tilt range
- ▶ Connect companion board directly to controller
- ▶ Test 3 separate methods for each fiducial system:
 - ▶ Raw/unfiltered marker pose
 - ▶ Filtered marker pose, e.g. KF

Future Work

- ▶ Use another drone platform
 - ▶ Phantom, Mavic, custom Tarot platform
 - ▶ More gimbal tilt range
- ▶ Connect companion board directly to controller
- ▶ Test 3 separate methods for each fiducial system:
 - ▶ Raw/unfiltered marker pose
 - ▶ Filtered marker pose, e.g. KF
 - ▶ Marker *position* and gimbal *orientation* for pose transforms

Main Messages

- ▶ *Actuated, gimbal-mounted camera*

Main Messages

- ▶ *Actuated, gimbal-mounted camera* → easier to search for the landing pad.

Main Messages

- ▶ *Actuated, gimbal-mounted camera* → easier to search for the landing pad.
- ▶ Orientation ambiguity, discontinuities

Main Messages

- ▶ *Actuated, gimbal-mounted camera* → easier to search for the landing pad.
- ▶ Orientation ambiguity, discontinuities → pose estimation is harder.

Main Messages

- ▶ *Actuated, gimbal-mounted camera* → easier to search for the landing pad.
- ▶ Orientation ambiguity, discontinuities → pose estimation is harder.
- ▶ Autonomous precision landing still possible

Main Messages

- ▶ *Actuated, gimbal-mounted camera* → easier to search for the landing pad.
- ▶ Orientation ambiguity, discontinuities → pose estimation is harder.
- ▶ Autonomous precision landing still possible but can be improved.

References

- ▶ Araar, Oualid and Aouf, Nabil and Vitanov, Ivan.
Vision Based Autonomous Landing of Multirotor UAV on Moving Platform.
Journal of Intelligent & Robotic Systems, 85, 02 2017.
- ▶ Alexandre Borowczyk, Duc-Tien Nguyen, André Phu-Van Nguyen, Dang Quang Nguyen, David Saussié, and Jerome Le Ny.
Autonomous Landing of a Multirotor Micro Air Vehicle on a High Velocity Ground Vehicle.
IFAC-PapersOnLine, 50(1):10488–10494, 2017.
20th IFAC World Congress.
- ▶ 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.