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

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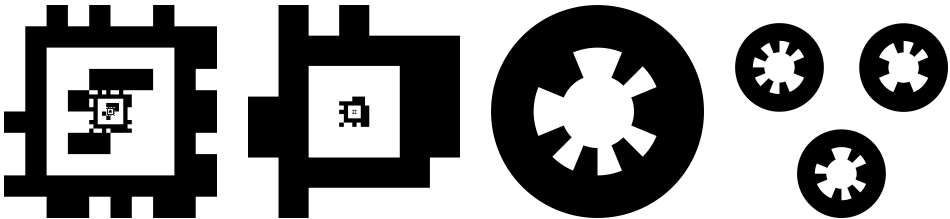
Fiducial Markers

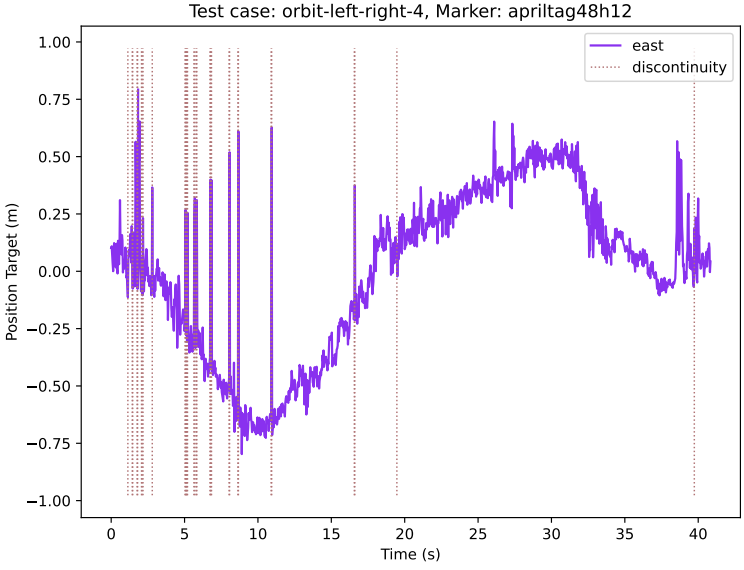


April Tag 48h12[1] April Tag 24h10 WhyCode[2] (Orig) WhyCode Multi

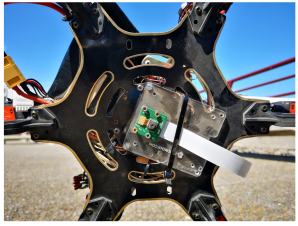
- Marker *position* $\rightarrow$ accurate
- Marker *orientation* $\rightarrow$ ambiguous

[1] Krogius, Haggenmiller, and Olson 2019.
[2] Lightbody, Krajník, and Hanheide 2017.

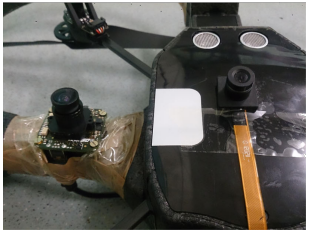
Orientation Ambiguity



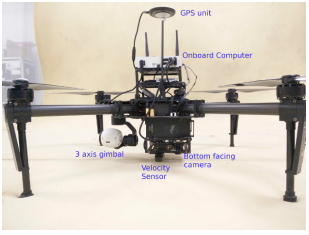
The Downward-facing Camera Paradigm



Single fixed camera.[3]



Dual fixed cameras.[4]



Gimbal/fixed cameras.[5]

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

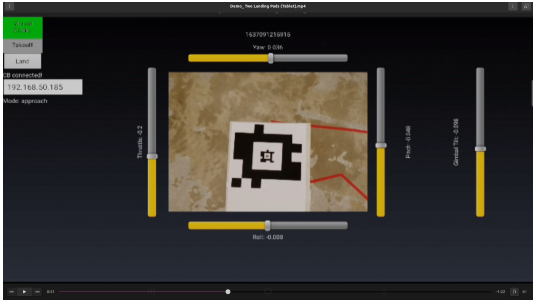
[3] Wubben et al. 2019.
[4] Araar, Oualid and Aouf, Nabil and Vitanov, Ivan 2017.
[5] Borowczyk et al. 2017.

Testing Platform: DJI Spark

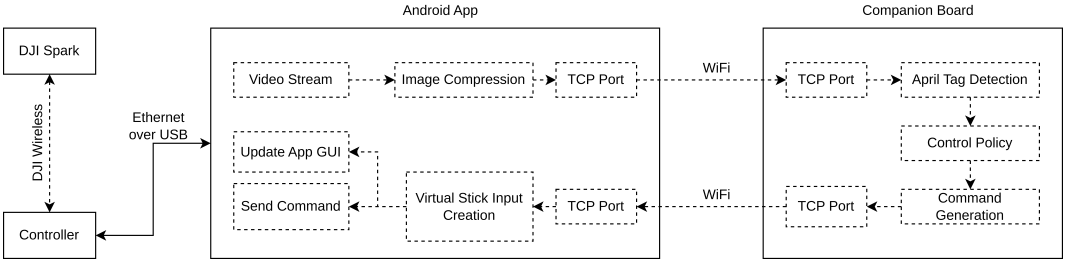
- Small quadcopter
- Gimbal-mounted camera
- DJI Mobile SDK

Testing Platform: Software Side

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

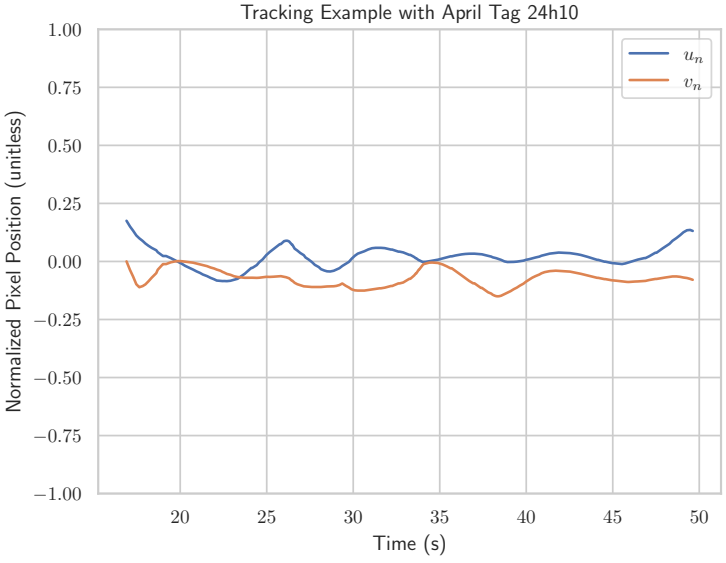


Data Flow

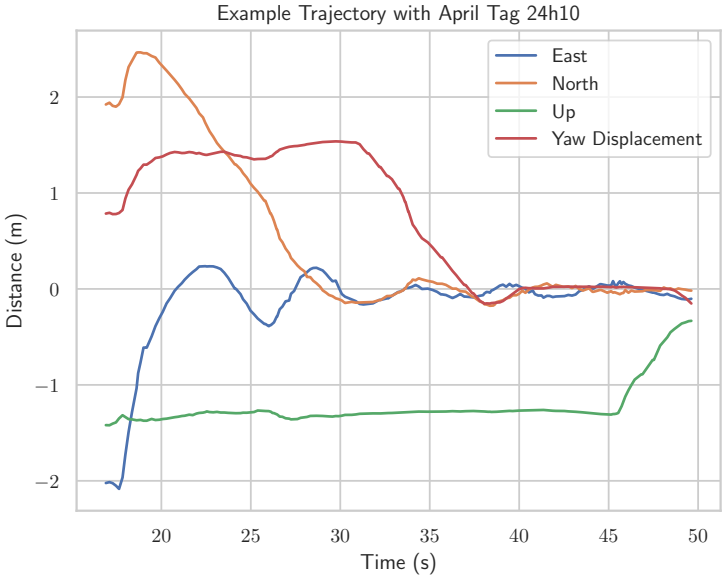


Demonstration Video

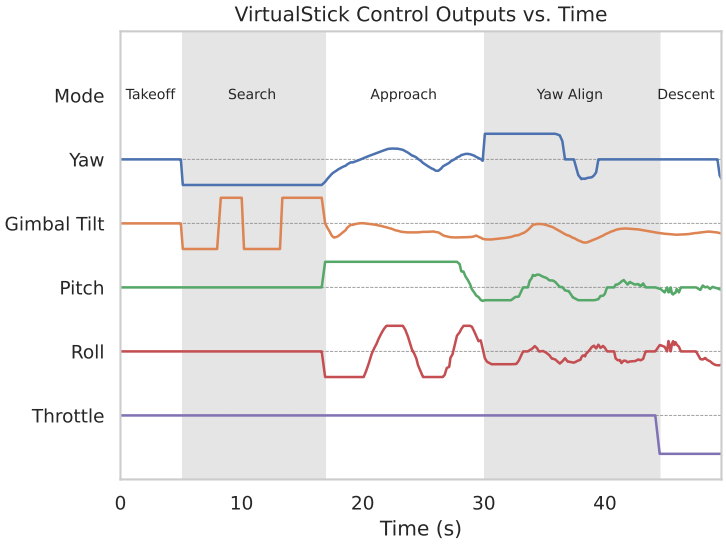
Example Tracking Performance



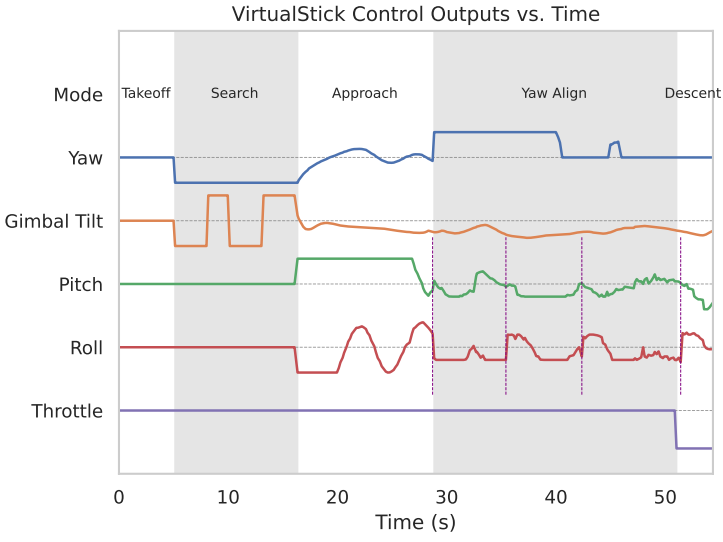
Example Landing Trajectory



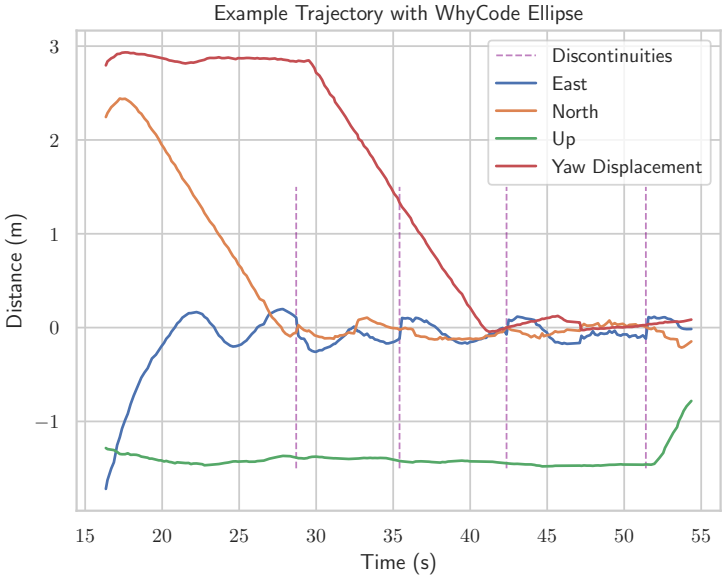
Example Control Outputs



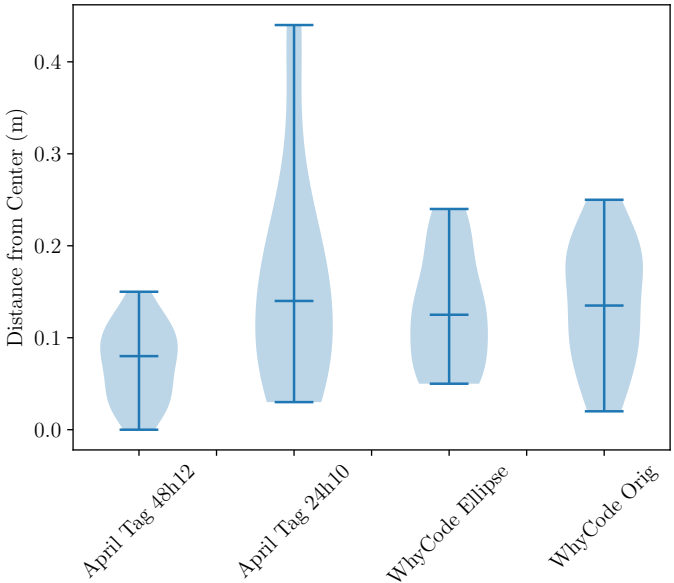
Control Outputs With Discontinuities



Landing Trajectory with Discontinuities



Landing Error (Lower is better!)



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- 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 → easier to search for the landing pad.

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- Orientation ambiguity, discontinuities $\rightarrow$ pose estimation is harder.
- Autonomous precision landing still possible but can be improved.