



# Evaluation of Orientation Ambiguity and Detection Rate in April Tag and WhyCode

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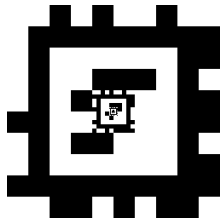
Joshua Springer, Marcel Kyas

7 December 2022

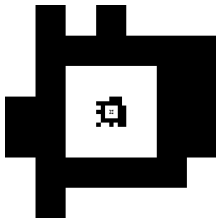
Reykjavik University

Department of Computer Science

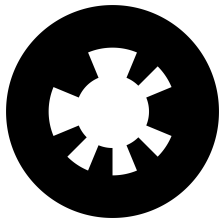
# Fiducial Markers



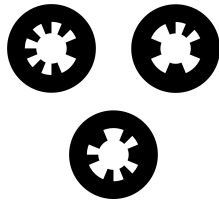
April Tag 48h12<sup>1</sup>



April Tag 24h10



WhyCode<sup>2</sup> (Orig)



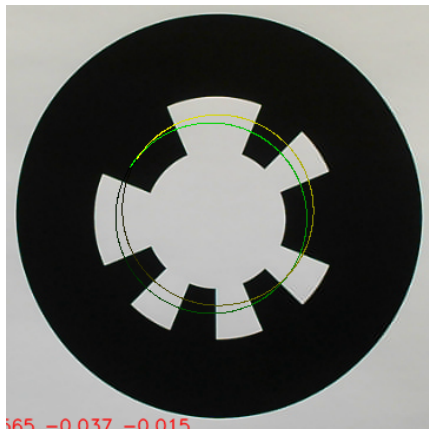
WhyCode Multi

- ▶ Marker *position* → accurate
- ▶ Marker *orientation* → ambiguous
- ▶ Application: autonomous drone landing (requiring pose transformation using the orientation)

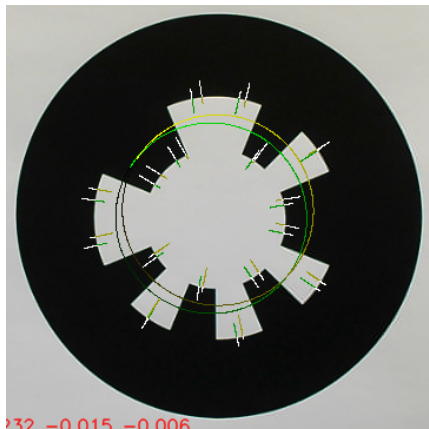
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<sup>1</sup>Krogus, Haggenmiller, and Olson 2019.

<sup>2</sup>Lightbody, Krajník, and Hanheide 2017.

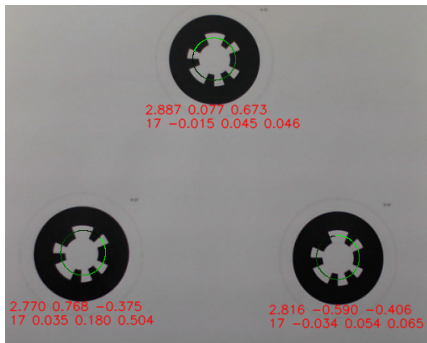


- ▶ Position → camera intrinsics, marker size (known)
- ▶ Orientation → two candidates (yellow/green ellipses)
  - ▶ Which one fits better?
  - ▶ Minimize variance of intersection length of sampling circle with each tooth

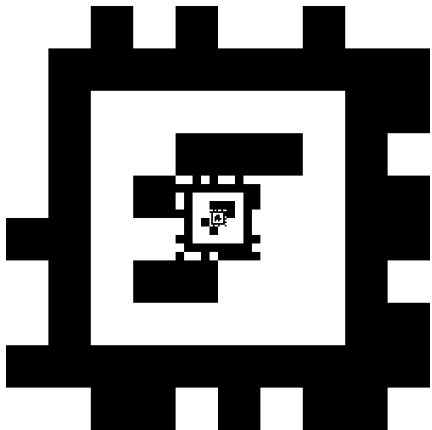


- ▶ Changes the method for choosing the orientation candidate
  - ▶ Original sampling predicts tooth transition locations
  - ▶ Sample again along radii through tooth centers
  - ▶ Try to center radial sampling lines on white-to-black transitions

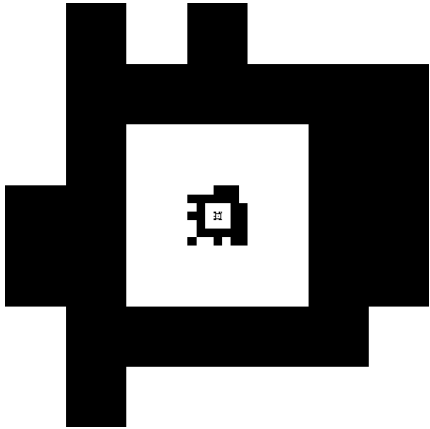
# WhyCode “Multi”



- ▶ Assumes coplanar marker arrangements
- ▶ Samples as in WhyCode Orig
- ▶ Uses only marker size, positions and IDs.
- ▶ Regresses a plane to the marker positions
- ▶ Assigns the plane's orientation to all of the markers



- ▶ 36 outer ID bits + 12 inner ID bits
- ▶ 28 black border bits
- ▶ 20 white border bits
- ▶ 4 undefined, center bits (for marker embedding)
- ▶ 42,211 markers in a single hash table in RAM



- ▶ 24 outer ID bits
- ▶ 16 black border bits
- ▶ 8 white border bits
- ▶ 1 undefined center bit (for marker embedding)
- ▶ 18 total markers (enough for our purposes)

- ▶ For autonomous landing application
- ▶ A **position target**  $P$  in the a relative “east, north, up” (ENU) coordinate frame
- ▶ The marker’s **orientation quaternion**  $q$



## Quantifying Orientation Ambiguity

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- ▶ Distances of 1-3 meters

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- ▶ Coplanar marker arrangement, same motion for all markers, all markers visible, 30cm side length
- ▶ Distances of 1-3 meters
- ▶ Creative Technology Live! Webcam at 480p, 30 fps
- ▶ Discontinuity rate:  $r_d = \frac{d}{n}$ : d is number of discontinuities, n is number of detections

## Linear Discontinuities

$$P = \langle p_e, p_n, p_u \rangle$$

$$\frac{p_{x,i+1}}{p_{x,i}} < \theta_l < 0$$

$$\theta_l = -0.8$$

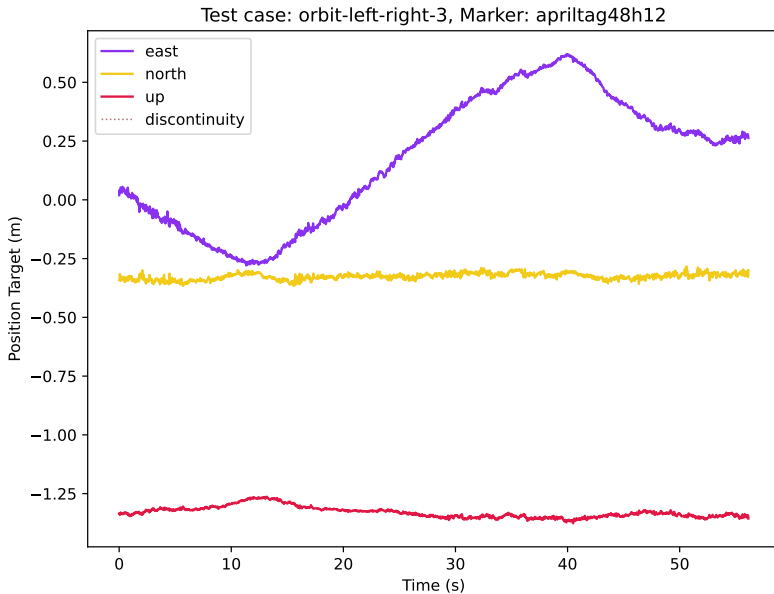
## Angular Discontinuities

$$q = \langle q_w, q_x, q_y, q_z \rangle$$

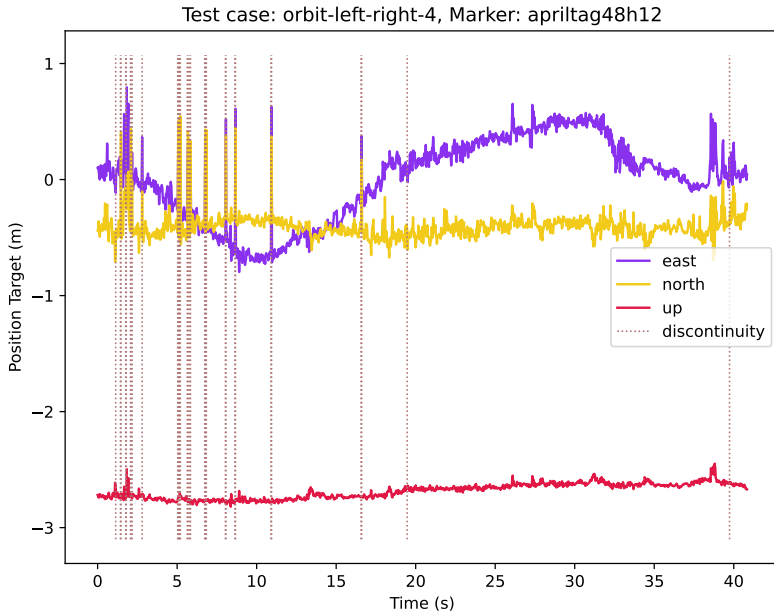
$$s_a = \left| \frac{\text{dist}(q_i, q_{i+1})}{t} \right| > \theta_a > 0$$

$$\theta_a = 1.0 \frac{\text{rad}}{\text{s}}$$

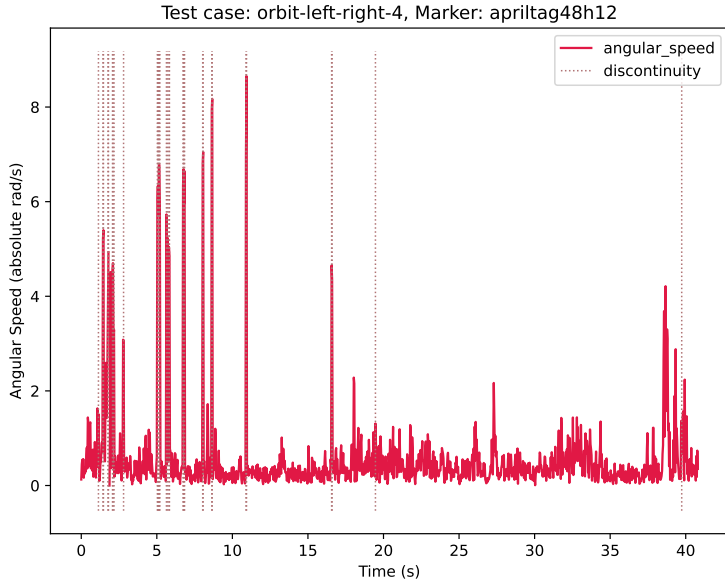
# Example Test Case



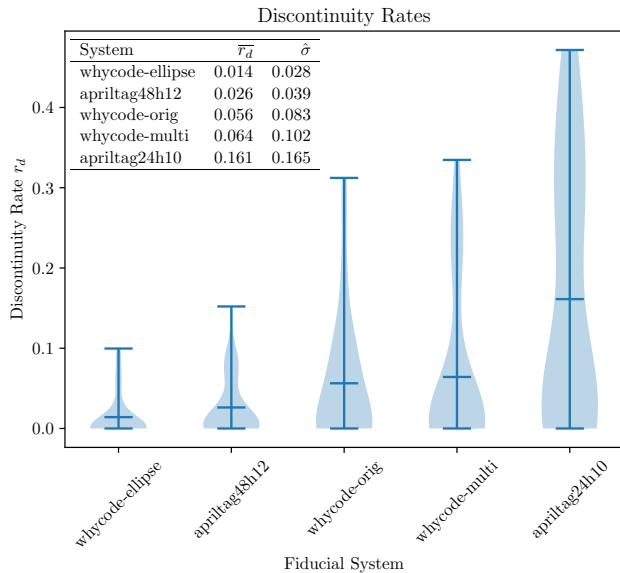
# Example Test Case with Discontinuities



# Example Test Case - Angular Speed



# Results: Discontinuity Rates (Lower is Better)

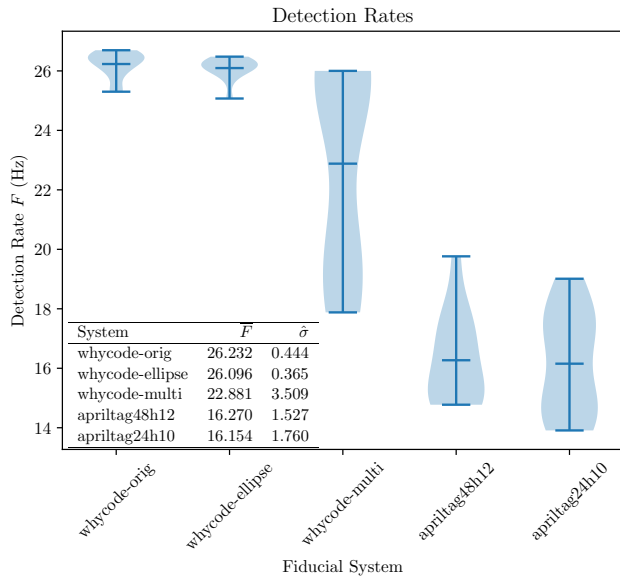




## Quantifying Detection Rate

- ▶ 16 test cases per marker
- ▶ distances of 0.6-3 meters (motivated by application)
- ▶ 8 normal, 8 with 45 degrees deflection
- ▶ One static marker per video
- ▶ Constant camera, framerate, resolution
- ▶ Detection rate:  $F = \frac{n}{t}$ : n is number of detections, t is the length in seconds of each test case
- ▶ Raspberry Pi 4 with 2 GB of RAM

# Results: Detection Rates (Higher is Better)



- ▶ Fiducial markers: orientation is hard to determine
  - ▶ Orientation ambiguity manifests as sign flips
  - ▶ Present in all fiducial systems, but at different rates
- ▶ Detection rate
  - ▶ Influenced by hardware capabilities, software architecture
- ▶ Application to autonomous landing with gimbal:
  - ▶ Most tested systems are worth trying
  - ▶ April Tag 24h10 is likely to have issues

