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

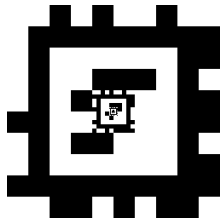Joshua Springer, Marcel Kyas

7 December 2022

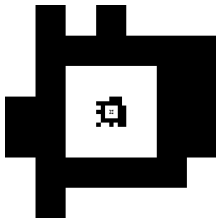Reykjavik University
Department of Computer Science

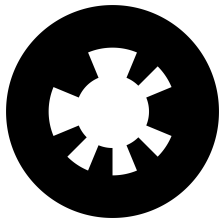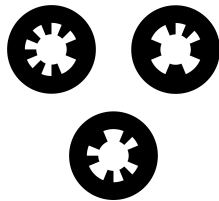April Tag 48h12[1]   April Tag 24h10   WhyCode[2] (Orig)   WhyCode Multi
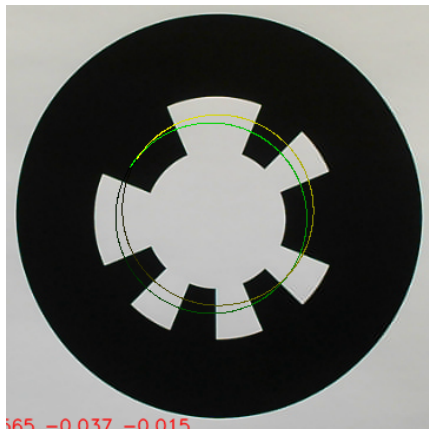
▶ Marker *position* → accurate

▶ Marker *orientation* → ambiguous

▶ Application: autonomous drone landing (requiring pose transformation using the orientation)

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

1

- 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

2
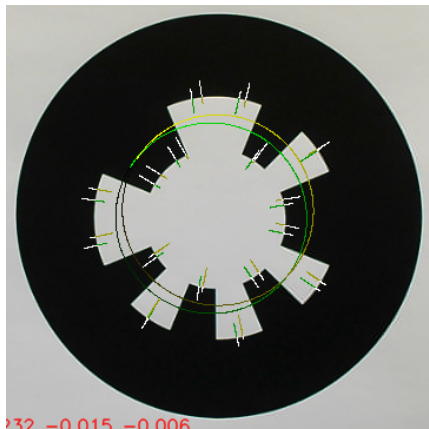
- ► Changes the method for choosing the orientation candidate
    - ► Original sampling predicts tooth transition locations
    - ► Sample again along radii through tooth centers
    - ► Try to center radial sampling lines on white-to-black transitions
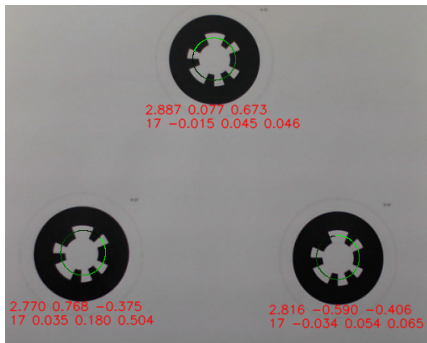
- ▶ Assumes coplanar marker arrangements
- ▶ Samples as in WhyCode Orig
- ▶ Uses only marker size, positions and IDs.
- ▶ Regresses a plane to the marker positions
- ▶ Assigns the plane's orientation to all of the markers
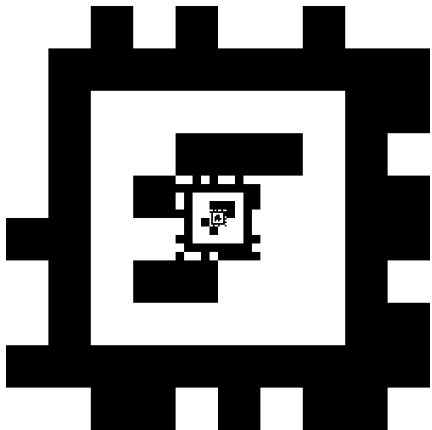
- ► 36 outer ID bits + 12 inner ID bits
- ► 28 black border bits
- ► 20 white border bits
- ► 4 undefined, center bits (for marker embedding)
- ► 42,211 markers in a single hash table in RAM
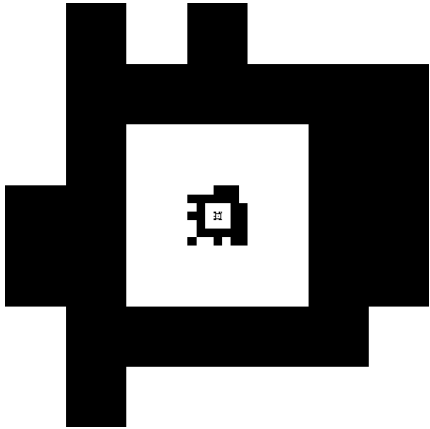
- ▶ 24 outer ID bits
- ▶ 16 black border bits
- ▶ 8 white border bits
- ▶ 1 undefined center bit (for marker embedding)
- ▶ 18 total markers (enough for our purposes)

- ▶ 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

$$P = \langle p_e, p_n, p_u \rangle$$
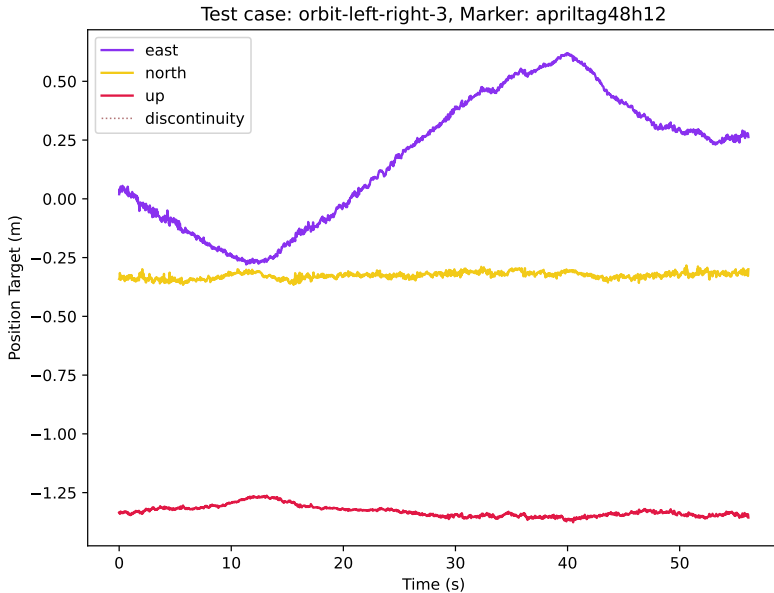$$\frac{p_{x,i+1}}{p_{x,i}} < \theta_l < 0$$
$$\theta_l = -0.8$$

Angular Discontinuities

$$q = \langle q_w, q_x, q_y, q_z \rangle$$
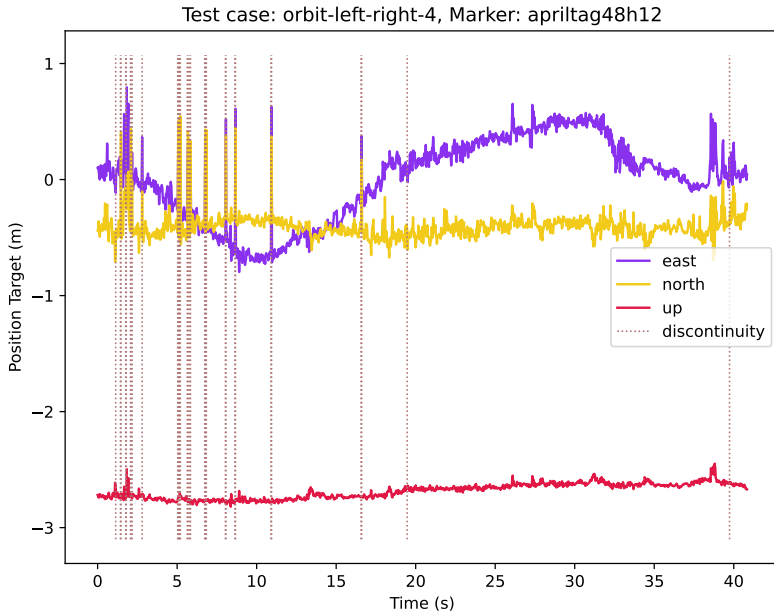$$s_a = \frac{\text{dist}(q_i, q_{i+1})}{t} > \theta_a > 0$$
$$\theta_a = 1.0 \frac{\text{rad}}{\text{s}}$$

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

Test case: orbit-left-right-4, Marker: apriltag48h12

Test case: orbit-left-right-4, Marker: apriltag48h12

Discontinuity Rates

System	$\overline{r_d}$	$\hat{\sigma}$
whycode-ellipse	0.014	0.028
apriltag48h12	0.026	0.039
whycode-orig	0.056	0.083
whycode-multi	0.064	0.102
apriltag24h10	0.161	0.165

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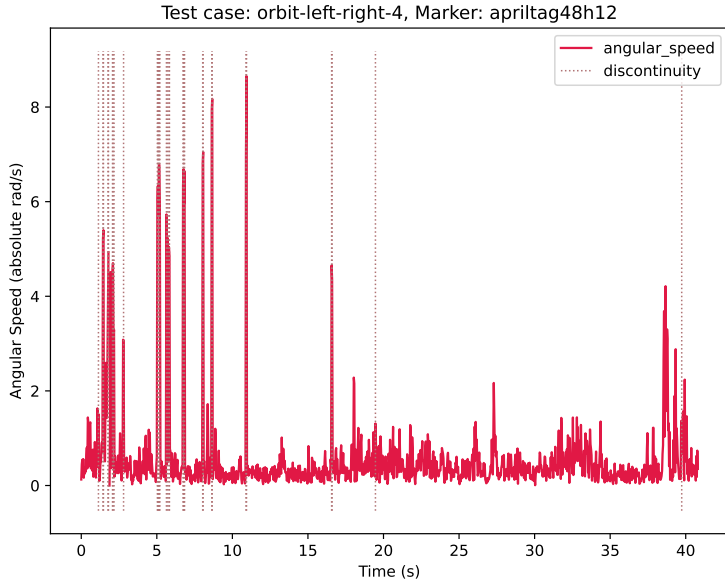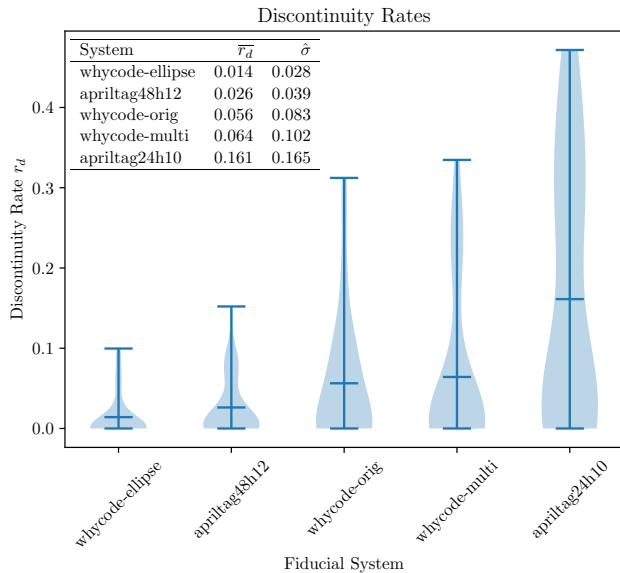
- ► 16 test cases per marker
- ► distances of 0.6-3 meters (motivated by application)
- ► 8 normal, 8 with 45 degrees deflection
- ► One static marker per video
- ► Constant camera, framerate, resolution
- ► Detection rate: $F = \frac{n}{t}$: n is number of detections, t is the length in seconds of each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

Detection Rates

System	$\overline{F}$	$\hat{\sigma}$
whycode-orig	26.232	0.444
whycode-ellipse	26.096	0.365
whycode-multi	22.881	3.509
apriltag48h12	16.270	1.527
apriltag24h10	16.154	1.760

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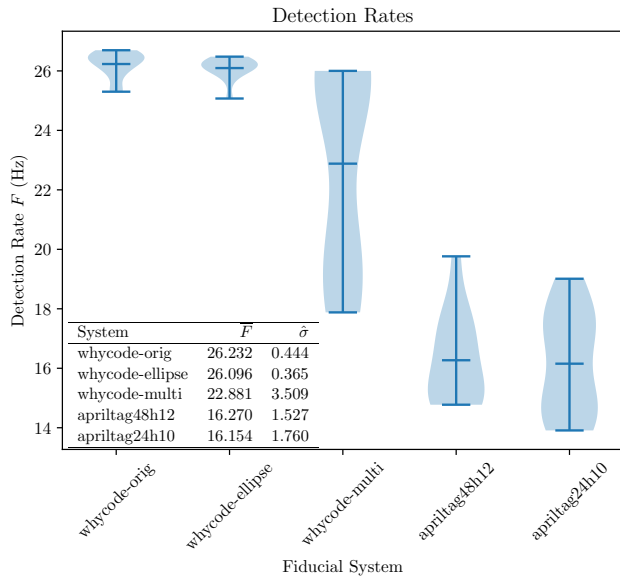
- ▶ Fiducial markers: orientation is hard to determine
  - ▶ Orientation ambiguity manifests as sign flips
  - ▶ Present in all fiducial systems, but at different rates
- ▶ Detection rate
  - ▶ Influenced by hardware capabilities, software architecture
- ▶ Application to autonomous landing with gimbal: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