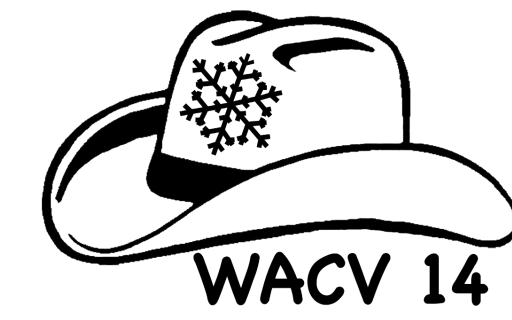


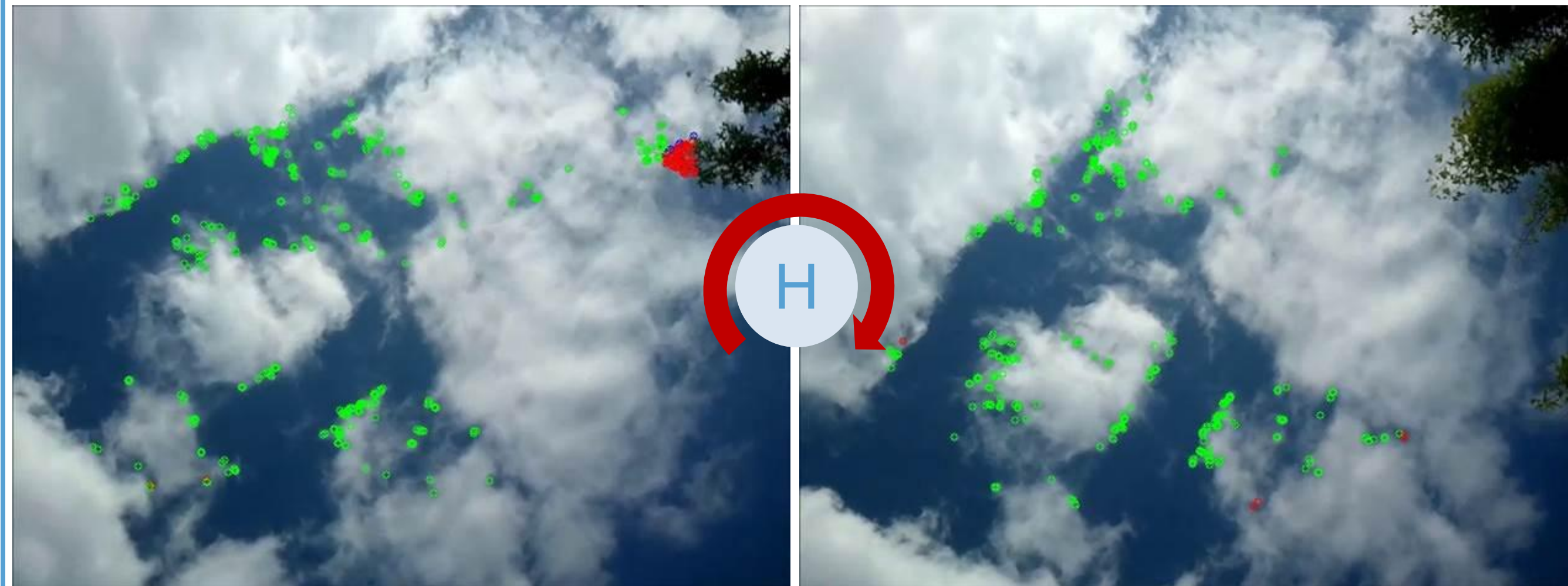


Rotation estimation from Cloud Tracking

Sangwoo Cho, Enrique Dunn, Jan-Michael Frahm {cswno, dunn, jmf}@cs.unc.edu Dept. of Computer Science, University of North Carolina at Chapel Hill

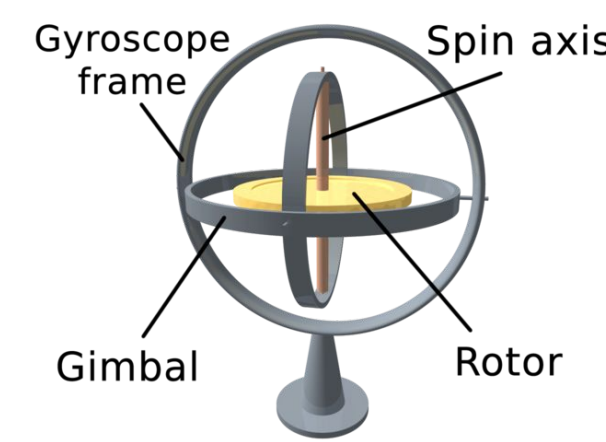


Motivation

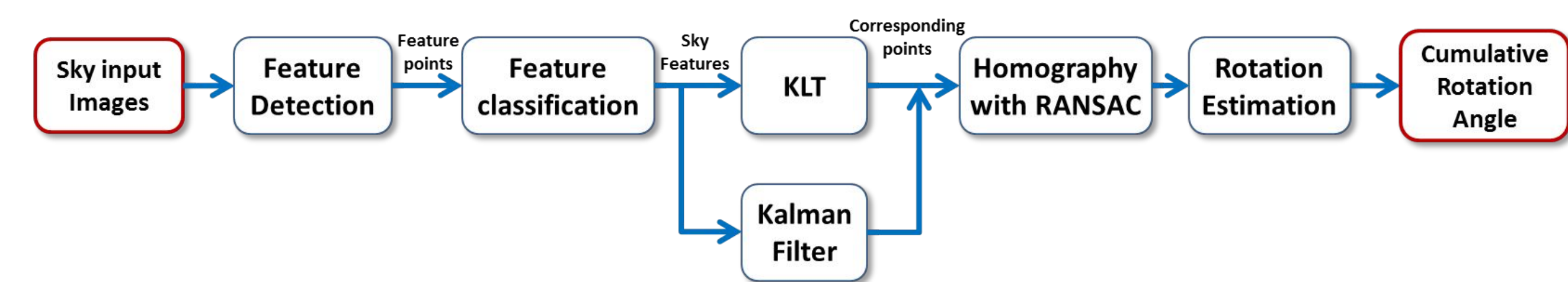


- Planar Homography between subsequent video frames
 - Rotation extracted from homography decomposition

- ✓ Convert a camera into a visual gyroscope
 - Estimation of a camera orientation from sky video
 - Use cloud structures as landmarks



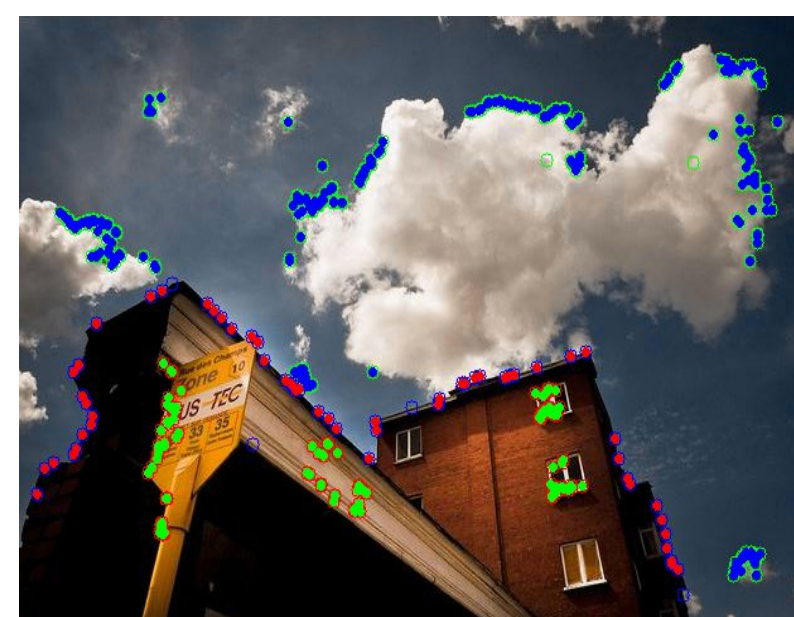
System overview



- Feature detection / selection
 - FAST features
 - Linear SVM training / Color histogram(17×17) descriptor
- Online feature tracking
 - KLT tracking
 - Kalman filter for occluders
 - Region-based feature update with adaptive threshold

Method

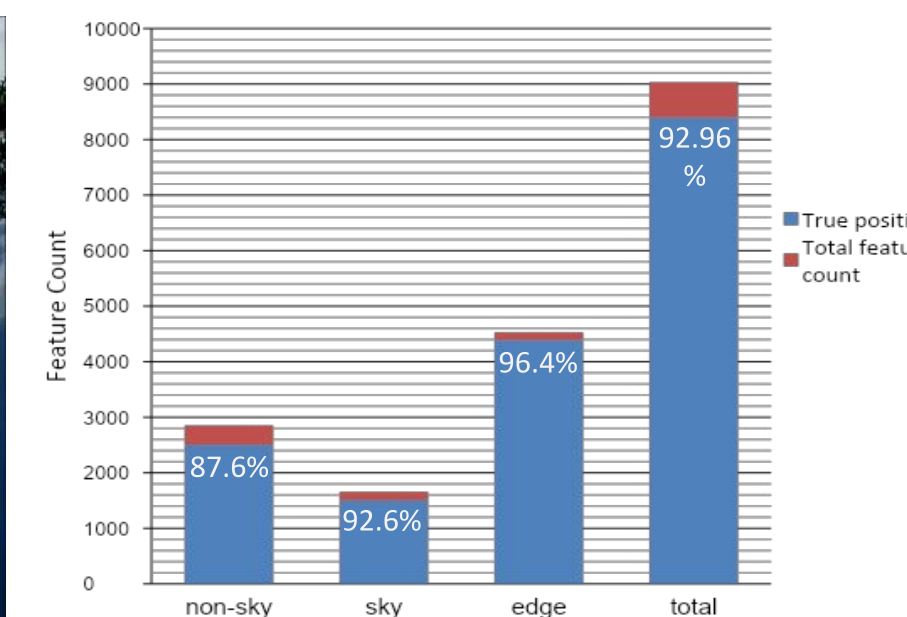
- Feature classification



Qualitative result



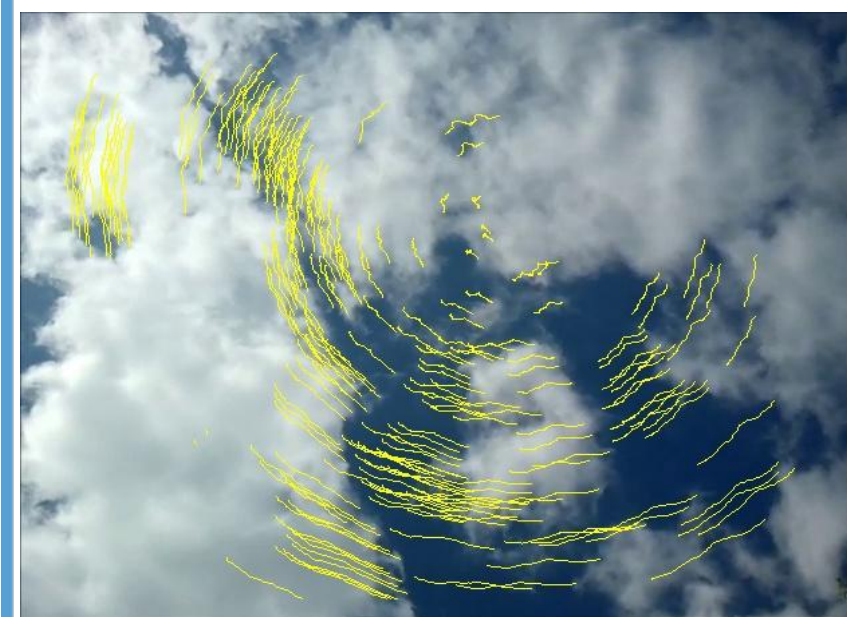
Qualitative result for sky image



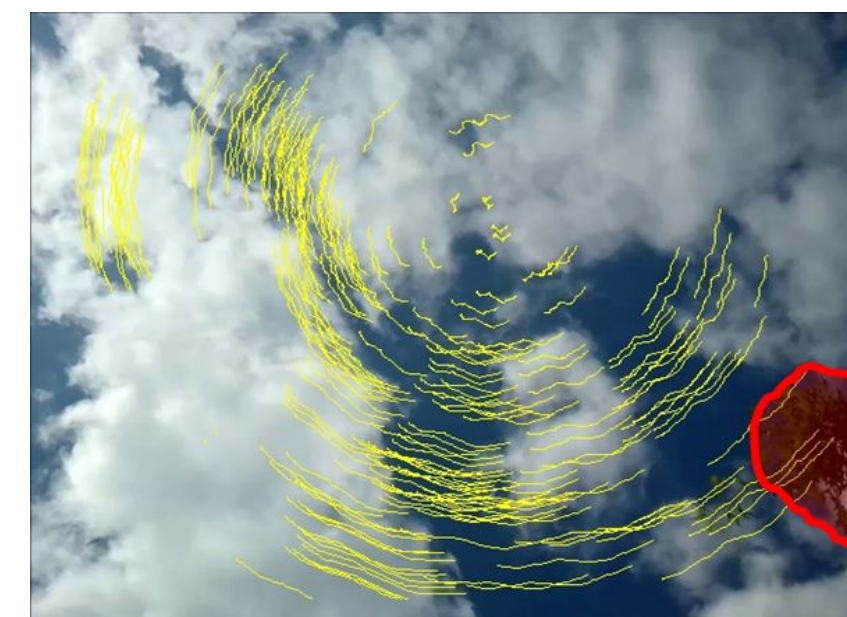
Classification accuracy

- Online feature tracking

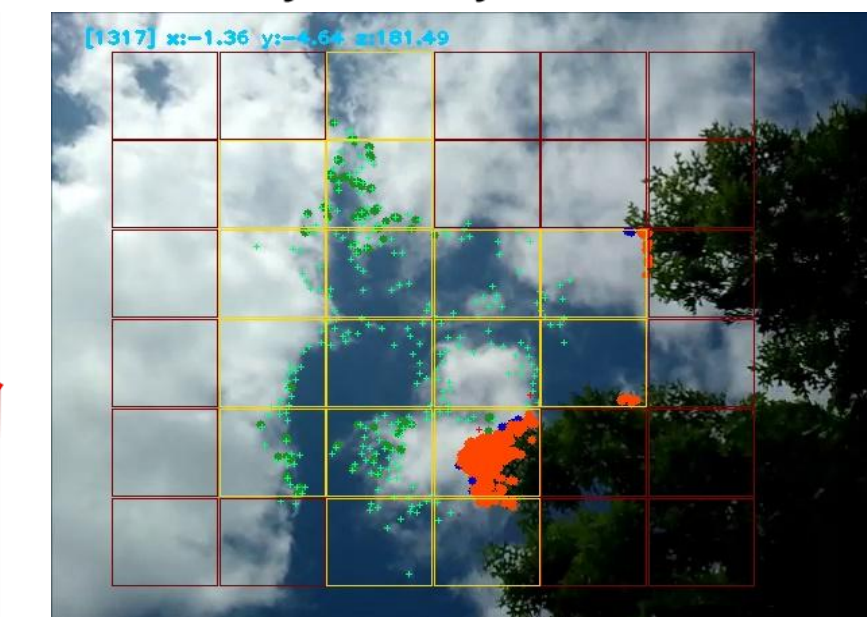
- KLT / Kalman filter / Region-based feature update
- Kalman filter : constant acceleration motion model $(x, y, V_x, V_y, A_x, A_y)$



KLT tracking

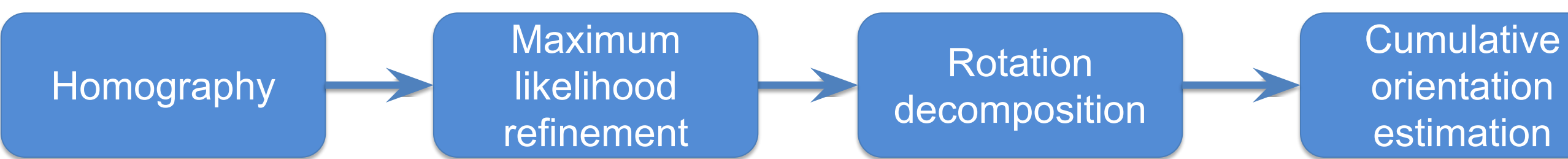


Kalman filter tracking



Region-based feature update

- Rotation estimation



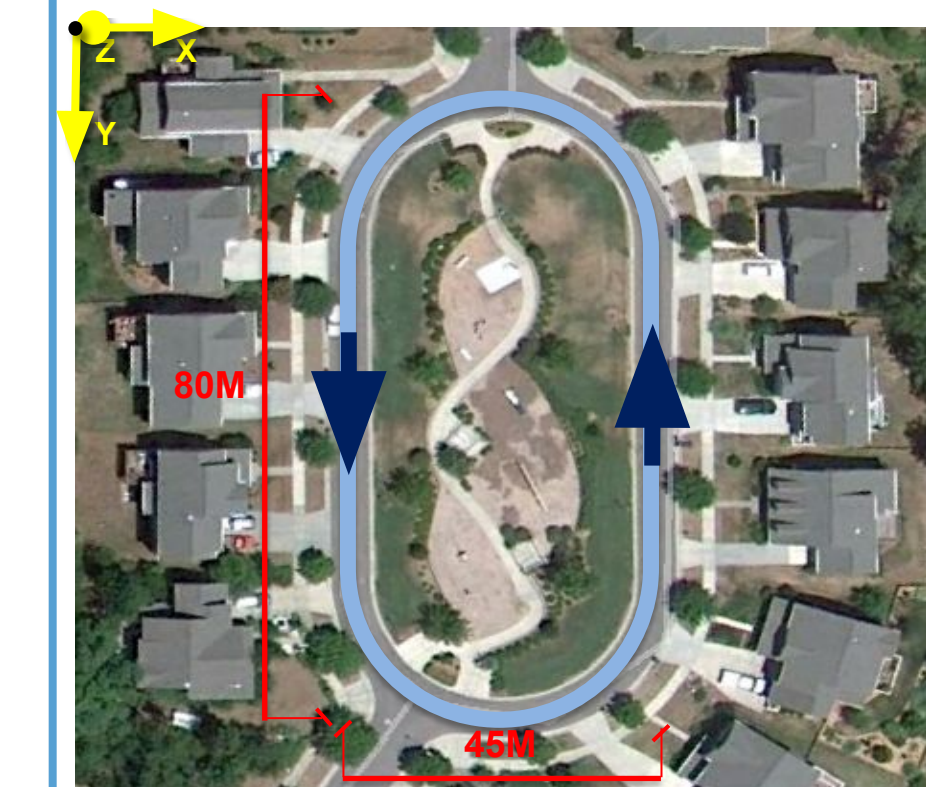
$$H = K(R + \frac{tn^T}{d}) K^{-1} = R + \frac{tn^T}{d} \rightarrow \{R_a, R_b\}^*$$

$$R = \begin{cases} R_a, & E_{R_a} < E_{R_b} \\ R_b, & E_{R_a} \geq E_{R_b} \end{cases} \begin{cases} E_{R_a} = \sum |x' - R_a x| \\ E_{R_b} = \sum |x' - R_b x| \end{cases}$$

* Malis et. al. Deeper understanding of the homography decomposition for vision-based control. Inria research report 6303, 2007

Experimental results

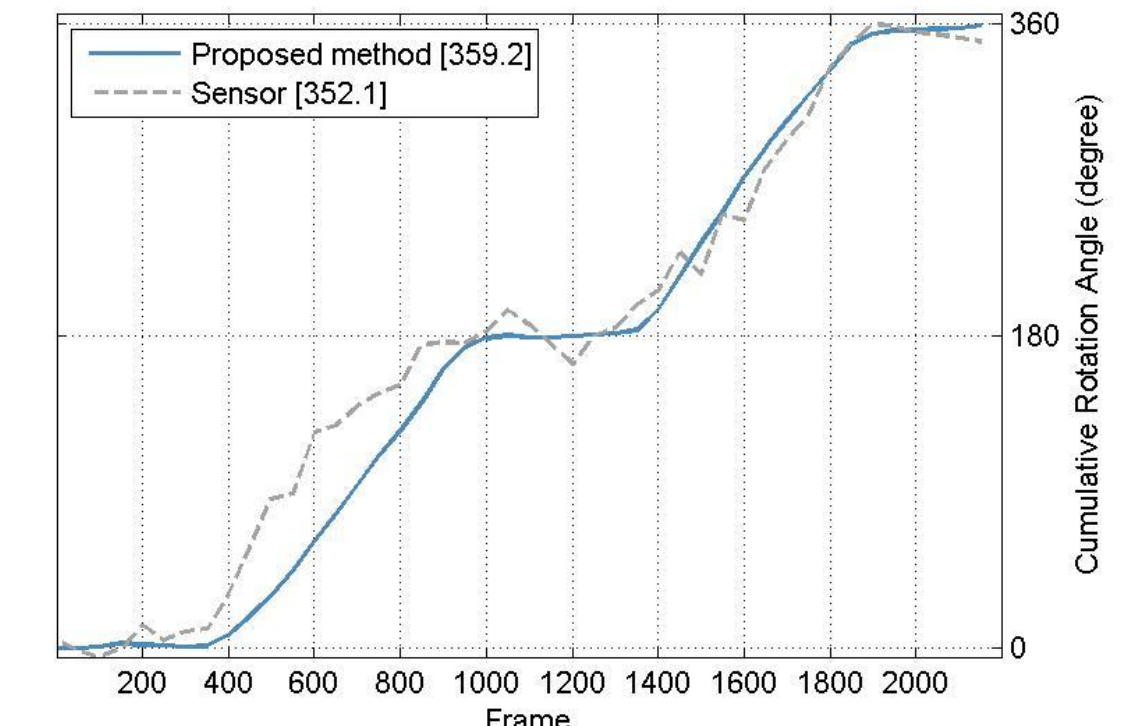
- 640x480 video (15Hz) with a mobile phone camera
- Compare against measurements from embedded gyro sensor
- Vehicle speed: 10~15 mph



Sample capture path



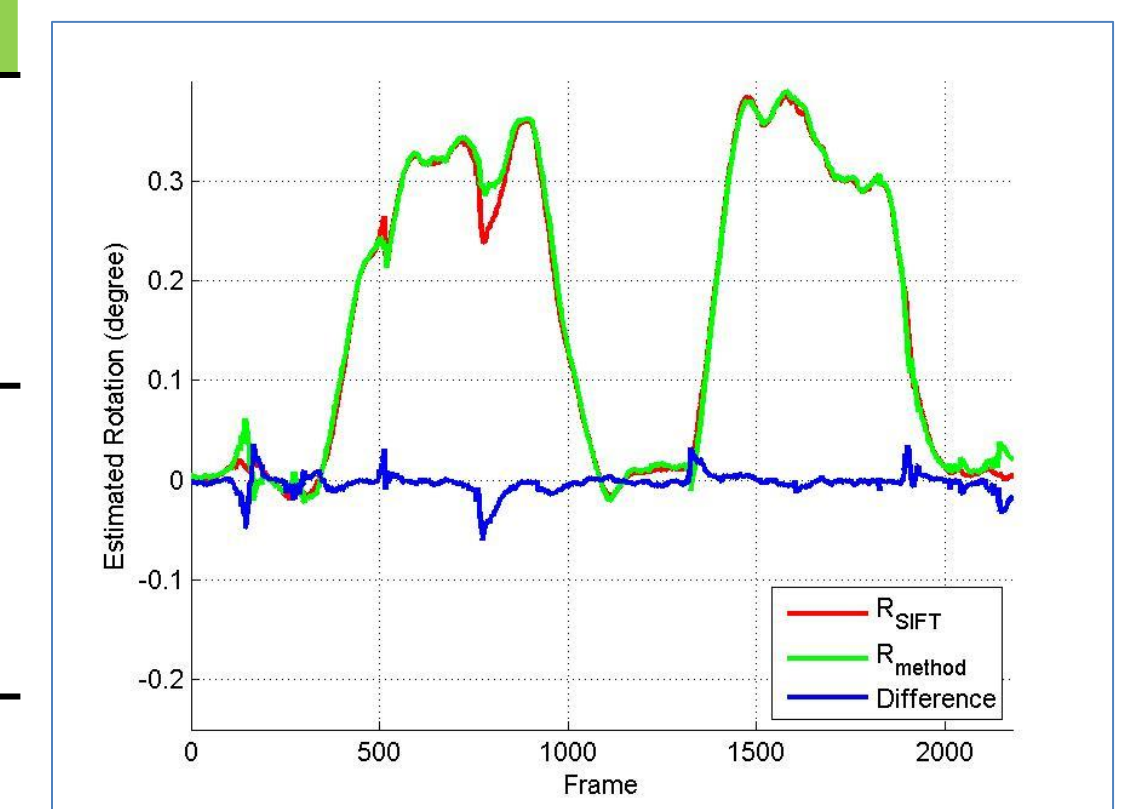
Camera setup



Proposed tracking vs Sensor data

Method	Estimated rotation angle
FAST + KLT + SVM ON + RANSAC ON + region-based ON	357.14
FAST + KLT + SVM OFF + region-based + RANSAC	330.91
FAST + KLT + SVM + region-based OFF + RANSAC	335.64
FAST + KLT + SVM + region-based + RANSAC OFF	342.04
FAST + KLT + SVM + region-based OFF + RANSAC OFF	325.36
FAST + KLT + SVM OFF + region-based + RANSAC OFF	323.71
FAST + KLT + SVM OFF + region-based OFF + RANSAC	318.18
FAST + KLT + SVM OFF + region-based OFF + RANSAC OFF	317.92

Performance of different module combinations



Proposed tracking vs SIFT landmarks

Contributions

- Accurate camera rotation estimation method using online cloud tracking
- Introduced a SVM classifier to segregate sky and non-sky features
- Proposed a region-based feature update method to increase accuracy when adding sky features
- Kalman filter based feature location prediction when occluders exist