Active Covariance Scaling for Feature Tracking Through Motion Blur

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Workshop on Scaling Up Active Perception

ICRA 2015, Seattle, USA

Institute for Aerospace Studies
UNIVERSITY OF TORONTO

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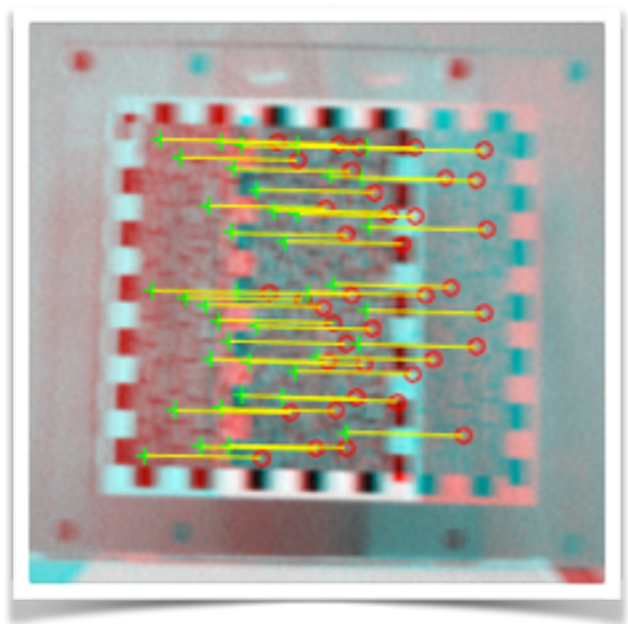
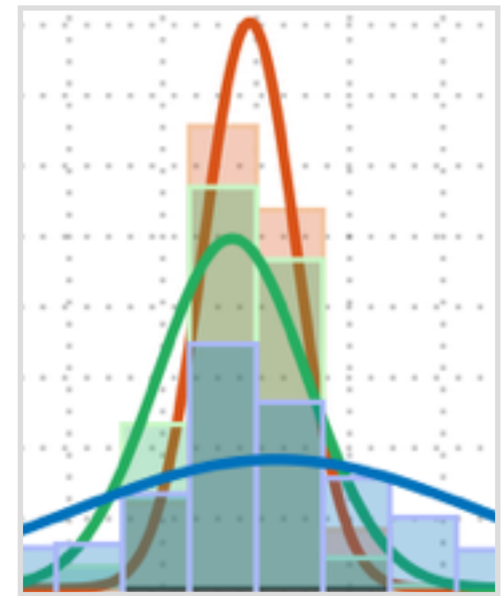
Outline: Motion Blur and Feature Tracking





1. Motivation

A simple way to detect and account for **motion blur** in sparse feature tracking.

2. Methods

KLT tracking of SURF, dataset of Gauglitz et al. 2011.

3. Results

Feature tracking error distributions under motion blur.

4. Application

Consistency of stereo visual odometry.

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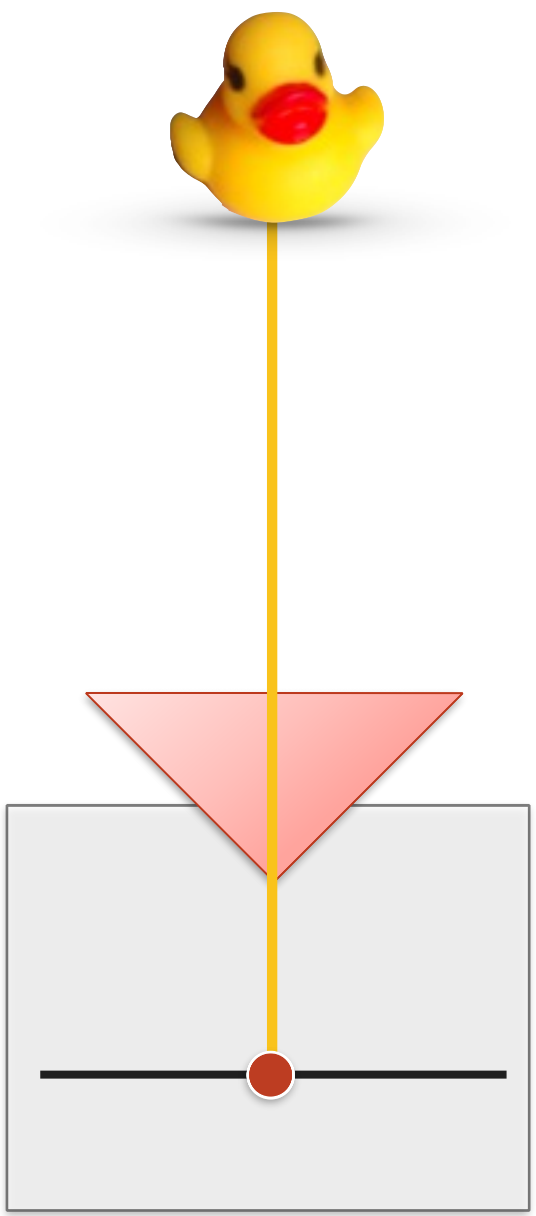
Motivation: Motion Blur Degrades Feature Tracking

In many robotics applications, fast-moving platforms require **accurate** and **consistent** estimates of their egomotion.

Sparse feature tracking commonly degrades in the presence of **motion blur**.

Some blurred features may be rejected as outliers, while others may carry useful information!

Background: What Is Motion Blur?



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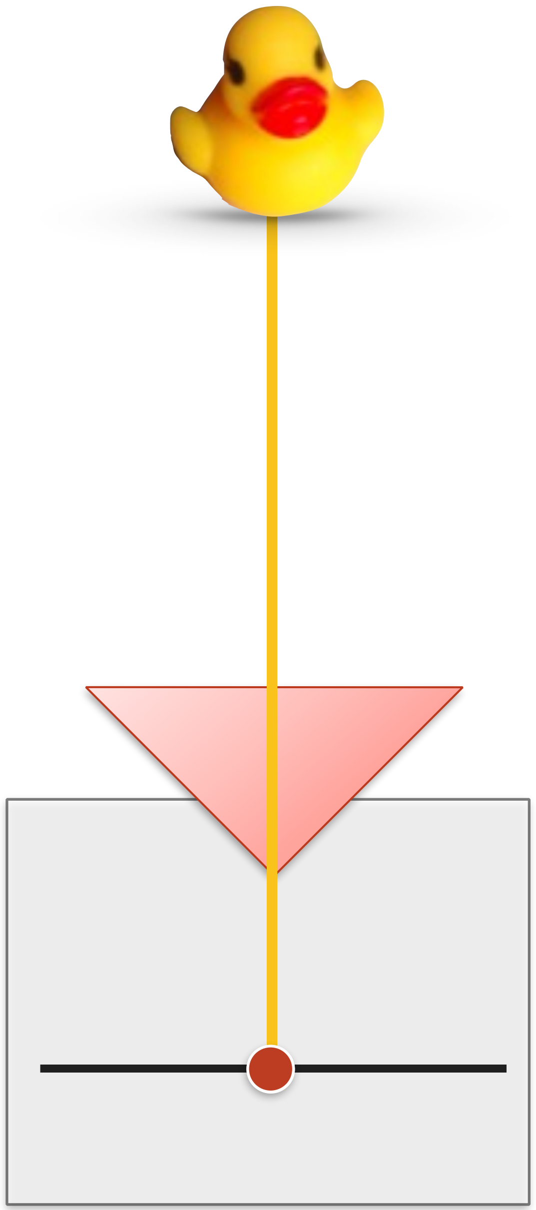

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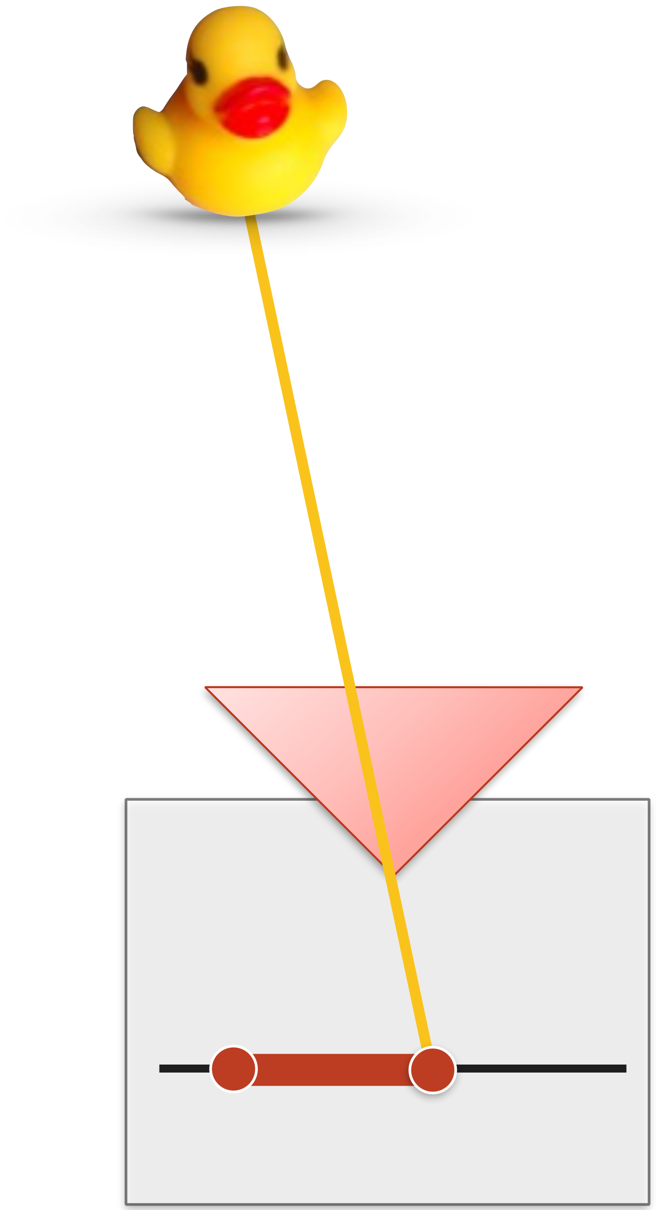

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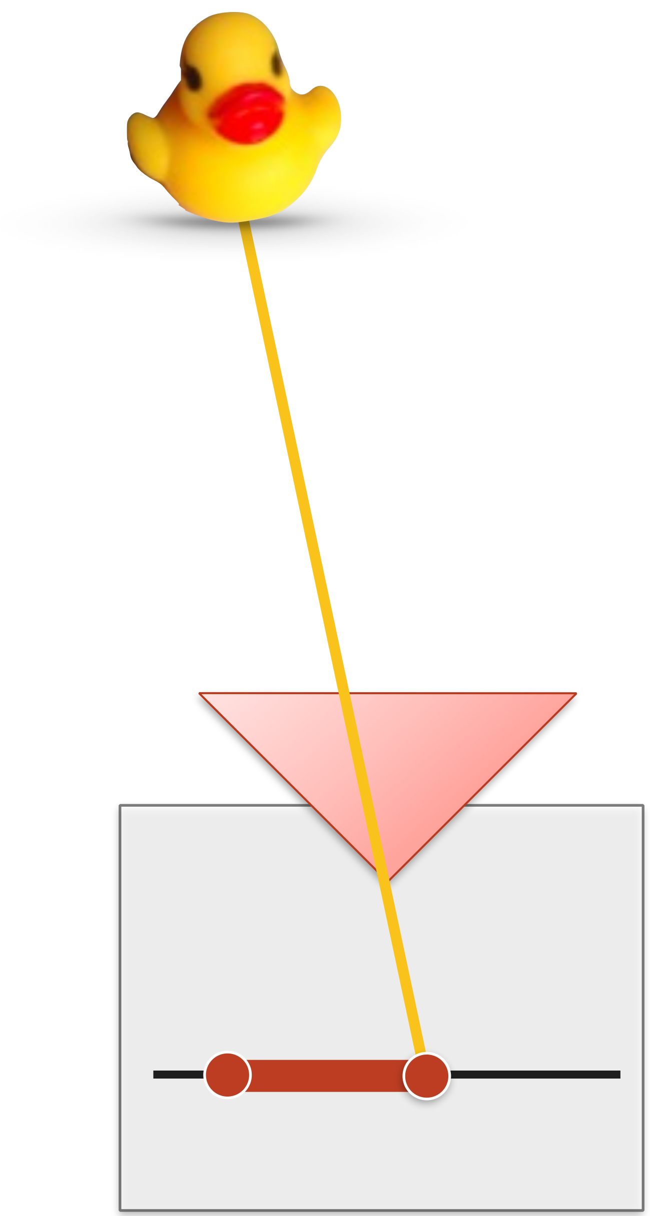

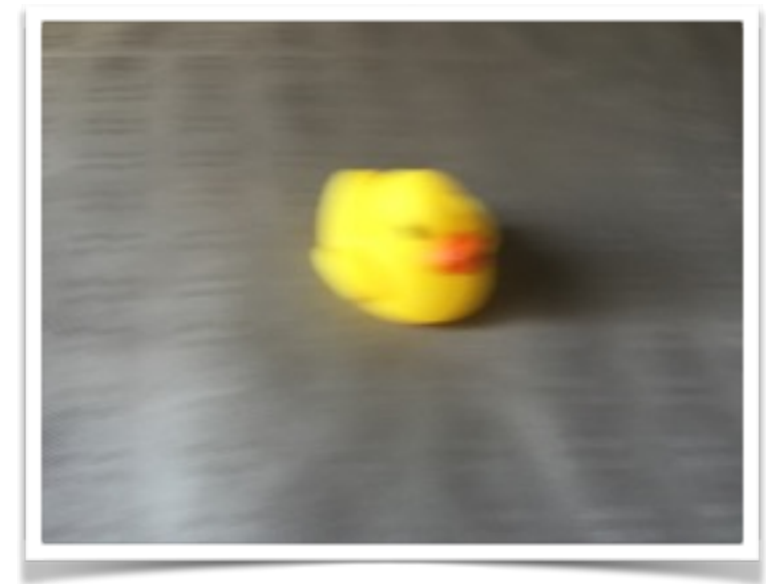

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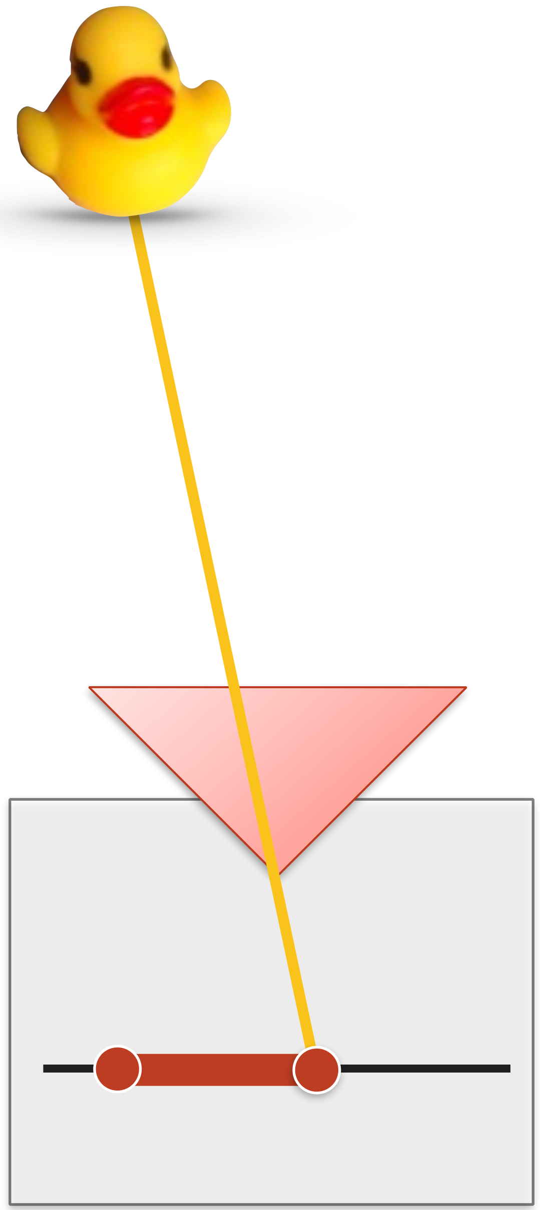

Note: translational motion blur depends on feature depth, but rotational motion blur is depth-independent and usually dominates.

Related Work: Compensating for Motion Blur

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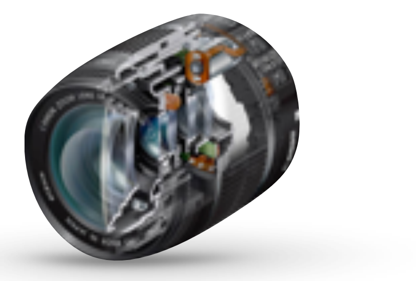
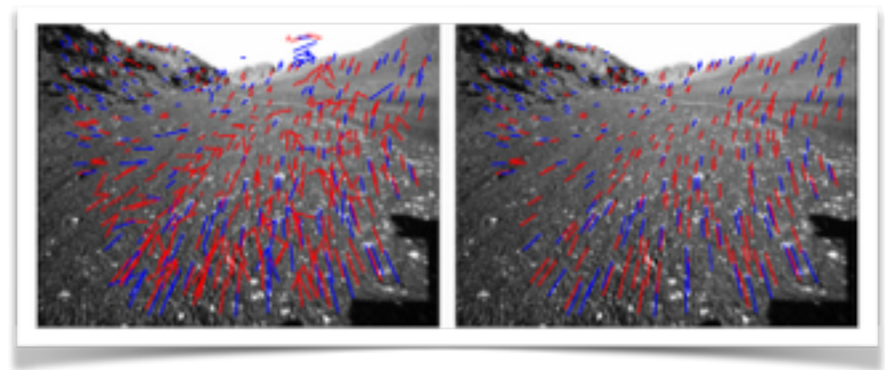
Image stabilization hardware



Related Work: Compensating for Motion Blur

Image stabilization hardware

Reject blurred features as outliers
(e.g., via RANSAC or similar)



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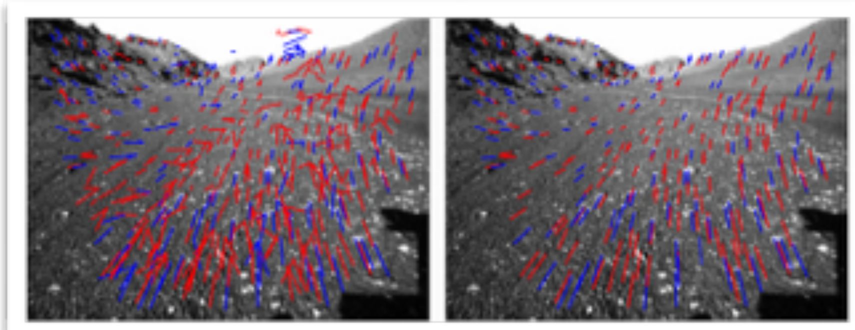
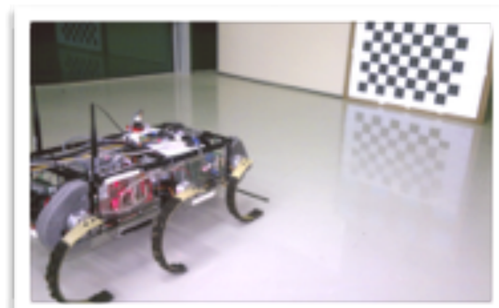


Drop video frames with blurred features

Mutlu et al., "**A real-time inertial motion blur metric**" ICRA 2014.



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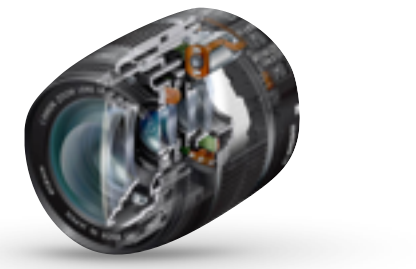

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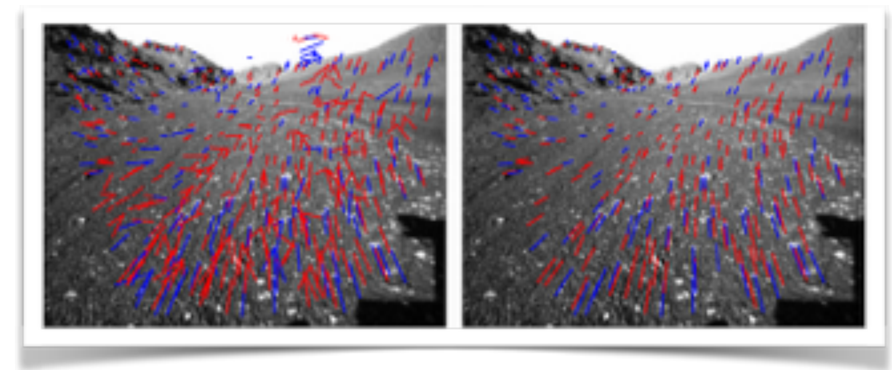

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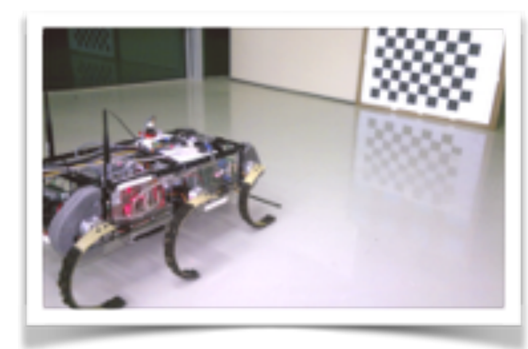
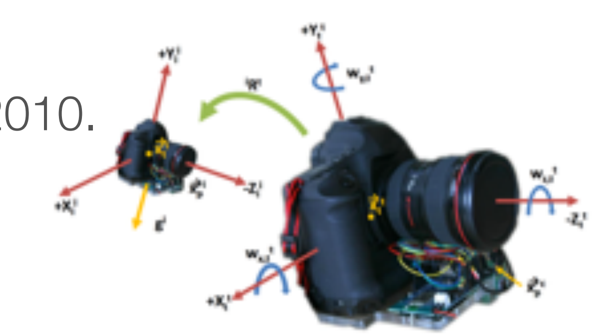


Attempt to compensate using a de-blurring technique

Joshi et al., "**Image deblurring using inertial measurement sensors**," ACM Trans. Graph., 2010.

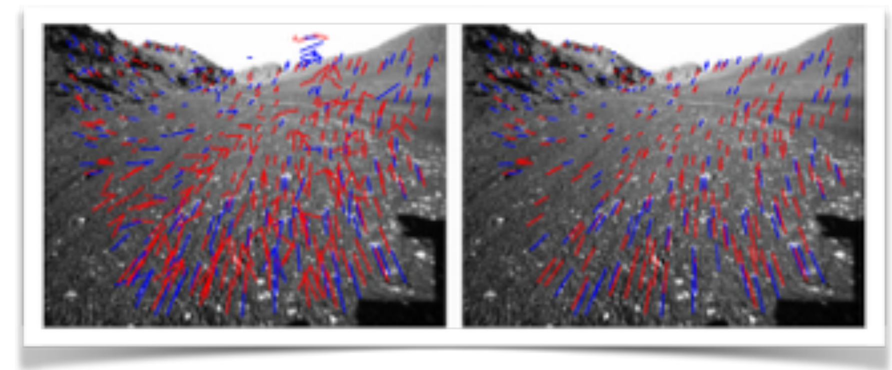


Related Work: Compensating for Motion Blur

Image stabilization hardware

- ⊗ Adds hardware complexity

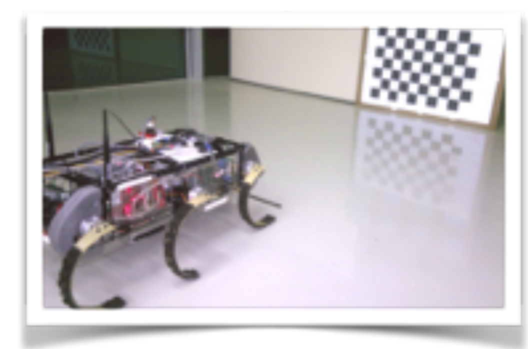
Reject blurred features as outliers (e.g., via RANSAC or similar)



- ⊗ Discards useful features

Drop video frames with blurred features

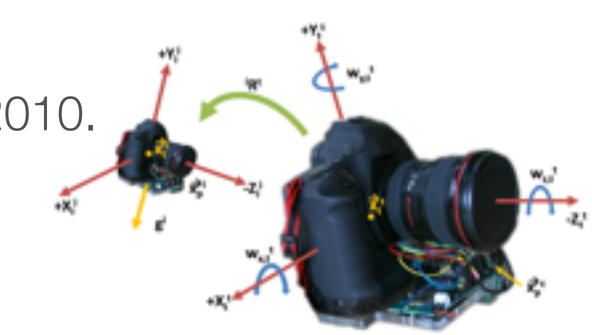
Mutlu et al., "**A real-time inertial motion blur metric**" ICRA 2014.



- ⊗ Removes entire images

Attempt to compensate using a de-blurring technique

Joshi et al., "**Image deblurring using inertial measurement sensors**," ACM Trans. Graph., 2010.

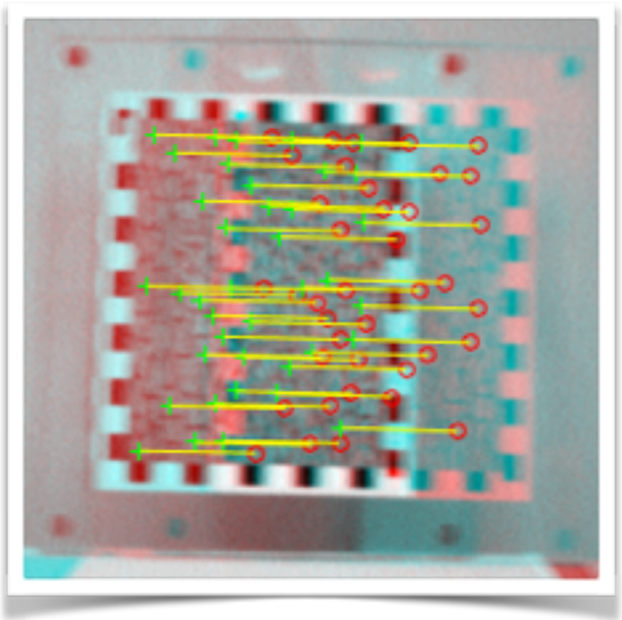


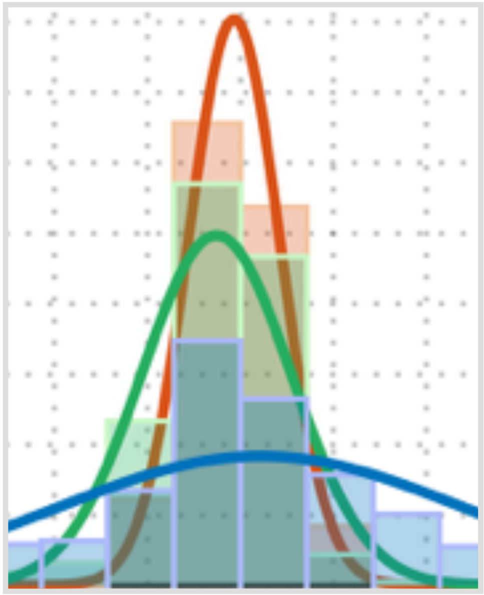
- ⊗ Designed for offline use

Our Idea: Modelling Tracking Through Motion Blur

Current approaches attempt to compensate for blur by preventing blurred feature tracks from entering the estimator.

? Can we **identify** motion blur and **characterize** its effect on tracking error?



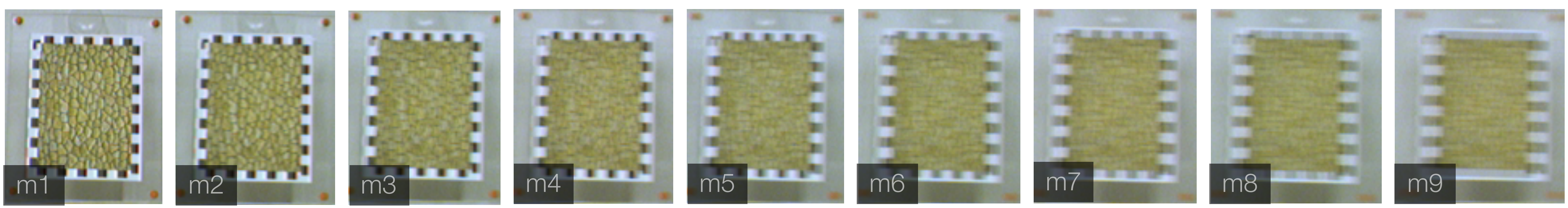


Dataset: Planar Texture, Moving Camera

We use the dataset of Gauglitz et al., in which a global-shutter camera on a pan-tilt head observes a planar texture while undergoing a panning motion.

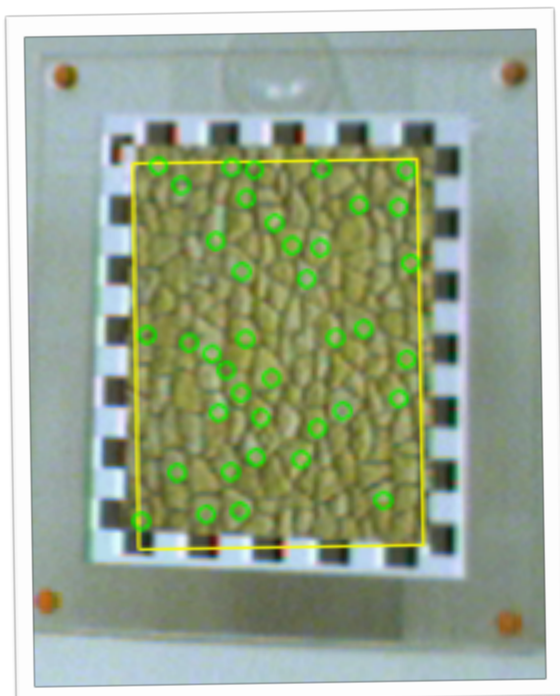
Six textures

Nine pan speeds



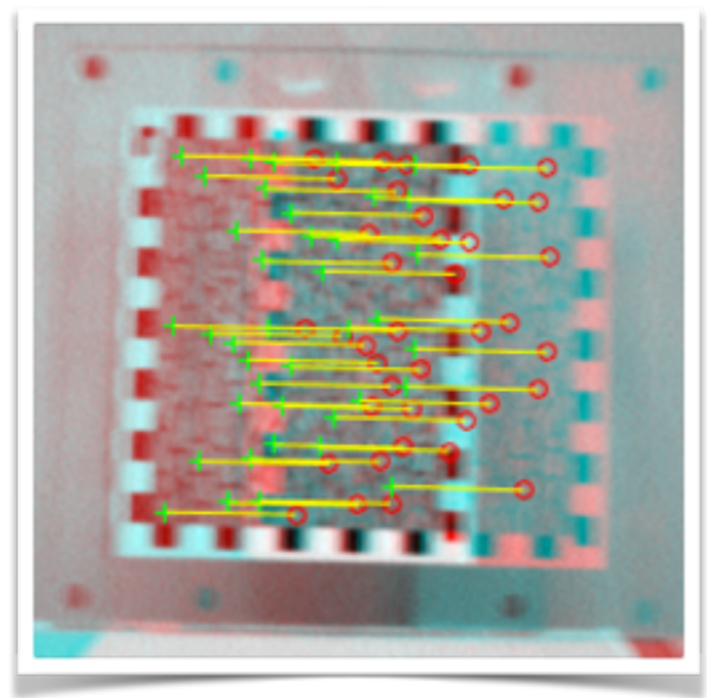
S. Gauglitz et al., “**Evaluation of interest point detectors and feature descriptors for visual tracking,**” IJCV 2011.

Quantifying Blur: Feature Tracking Error



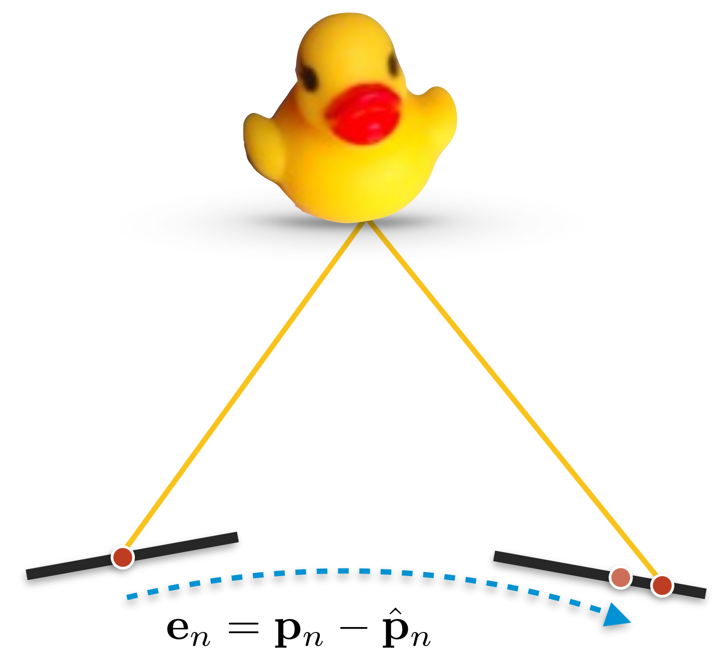
Detect point features
(e.g., using SURF, FAST, Harris).

1



Track features using
Kanade-Lucas-Tomasi (KLT).

2

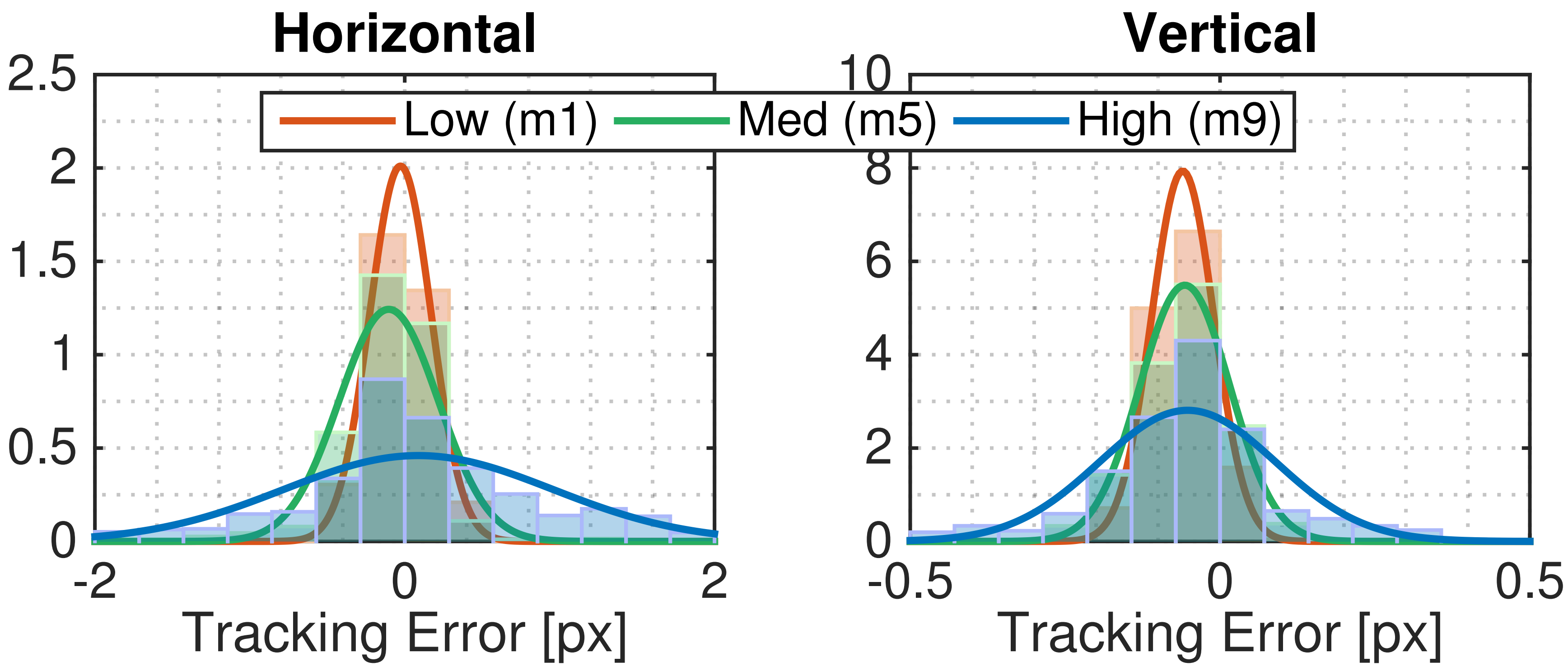


$$\mathbf{e}_n = \mathbf{p}_n - \hat{\mathbf{p}}_n$$
$$= \mathbf{H}_{n,n-1}\mathbf{p}_{n-1} - \hat{\mathbf{p}}_n$$

Compute **frame-to-frame**
reprojection error using
ground truth homographies.

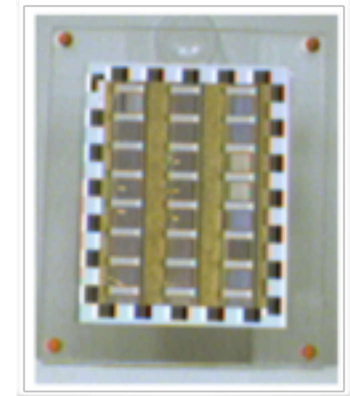
3

Quantifying Blur: Feature Tracking Error

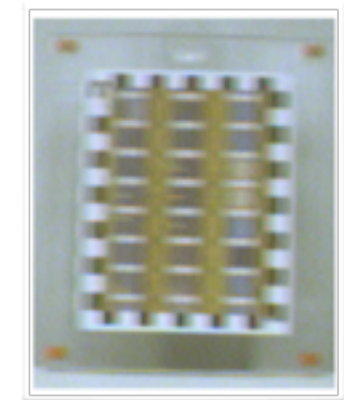


	Mean [px]	*Stdev [px]*
m1	*-0.03*	*0.20*
m5	*-0.10*	*0.32*
m9	*0.09*	*0.87*

	Mean [px]	*Stdev [px]*
m1	*-0.06*	*0.05*
m5	*-0.06*	*0.07*
m9	*-0.05*	*0.14*



m1: 0.0278 deg/s

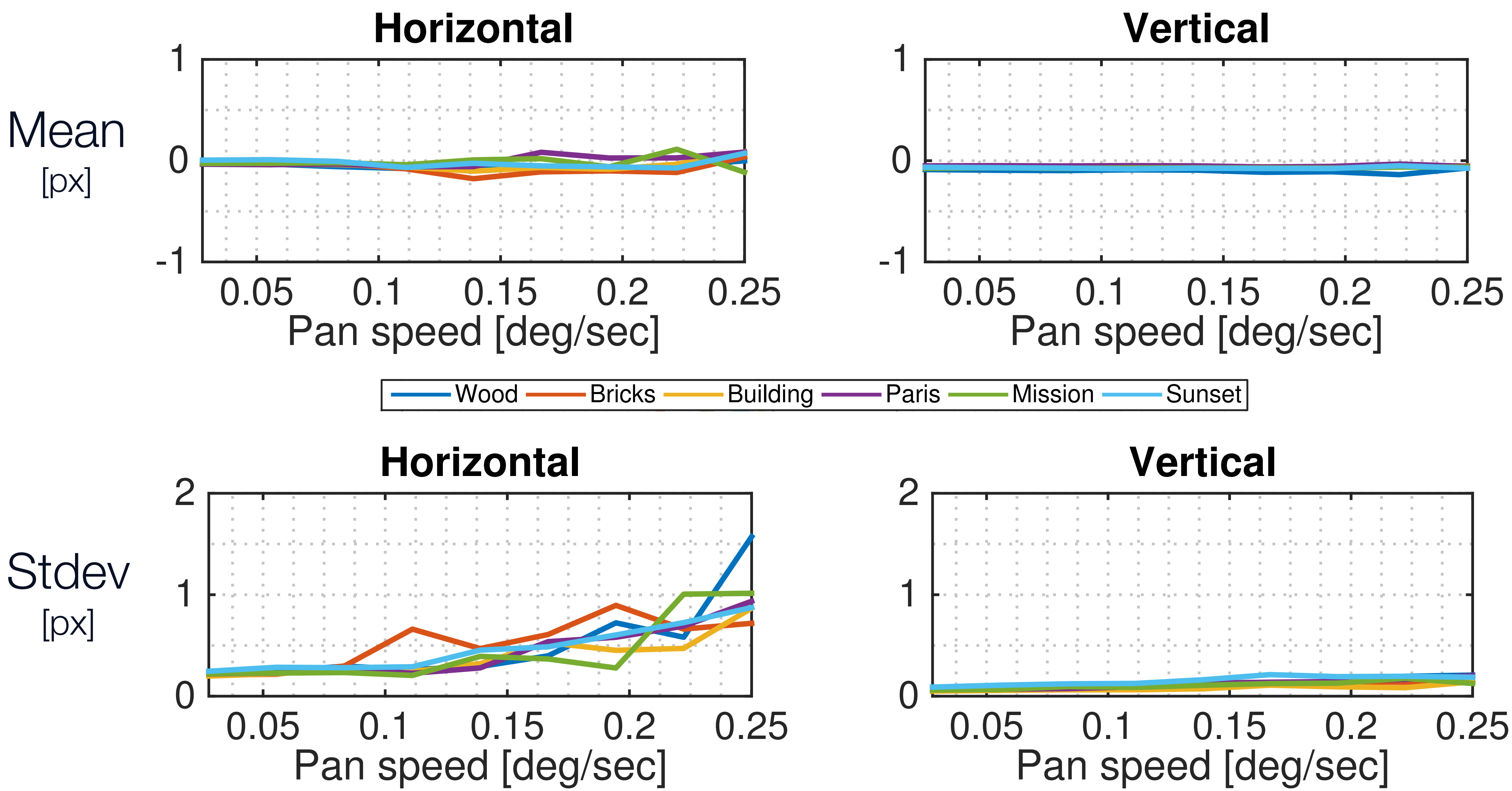


m5: 0.1385 deg/s

m9: 0.2493 deg/s

Motion blur **inflates variance** of KLT tracking error while keeping it **zero-mean**.

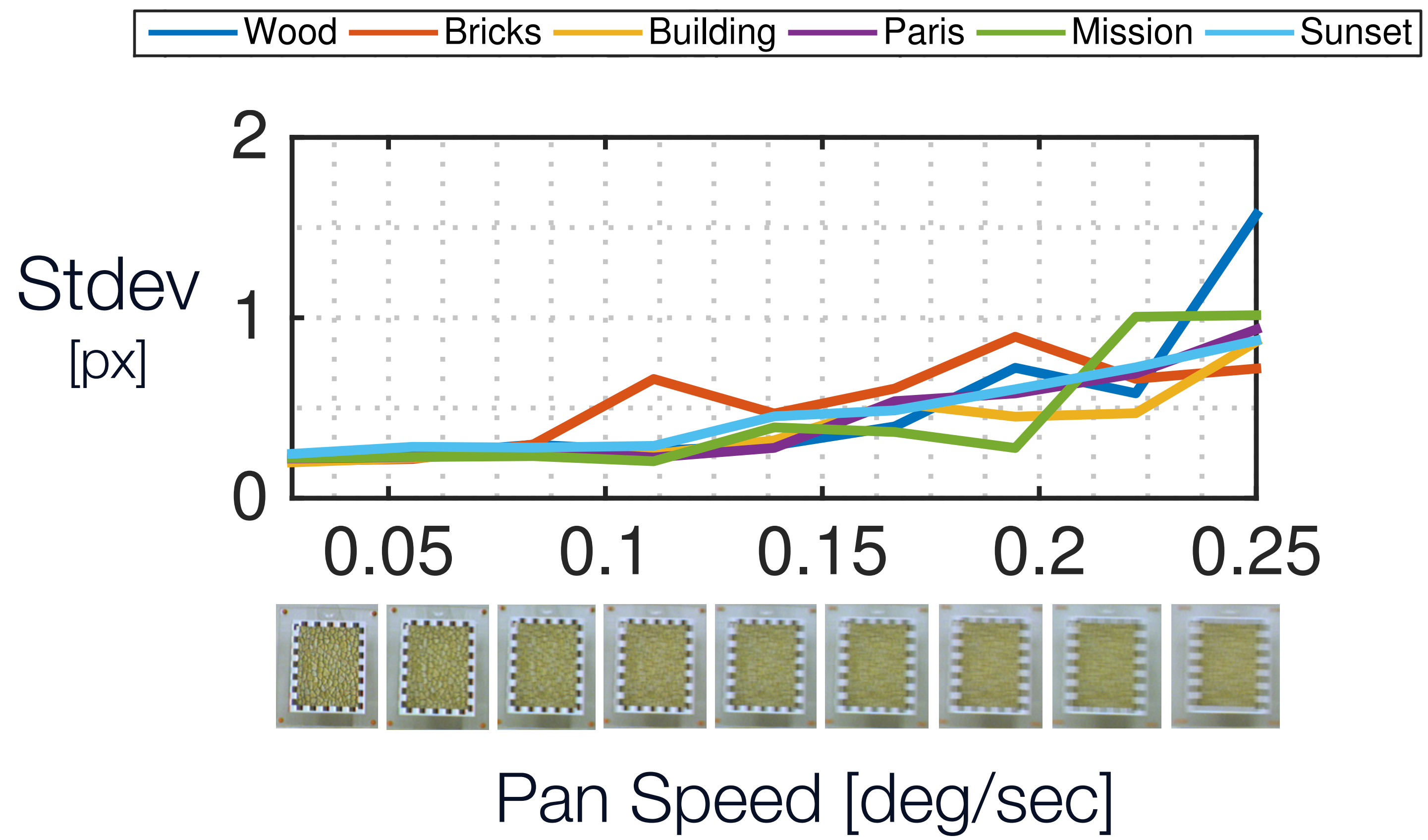
Quantifying Blur: Error Variance Increases with Pan Speed



Note: Horizontal blur dominates because the motion is mainly horizontal.

Identifying Blur: Visual vs. Inertial Cues

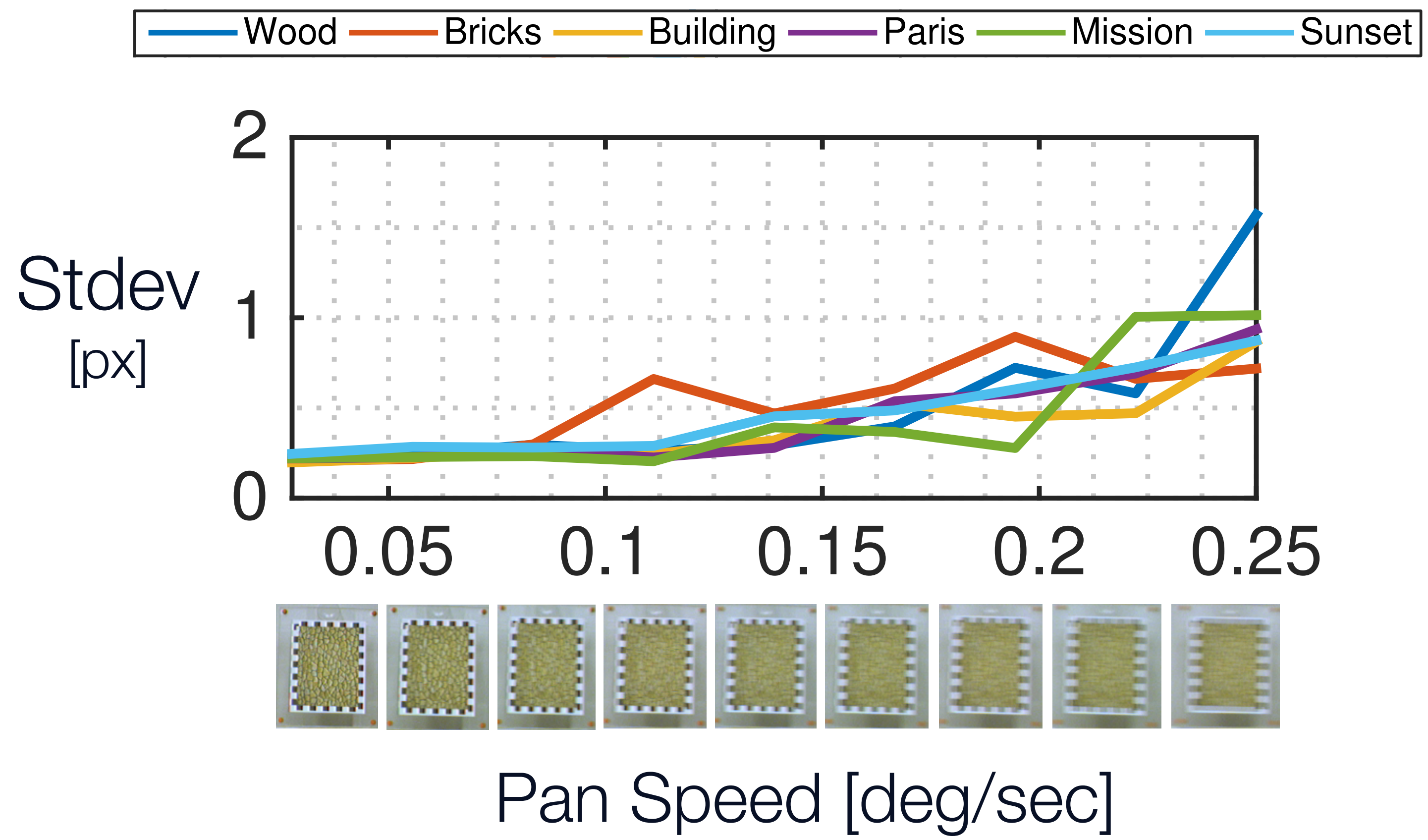
A **gyroscope** that reports angular rates could be used to predict motion blur.



Identifying Blur: Visual vs. Inertial Cues

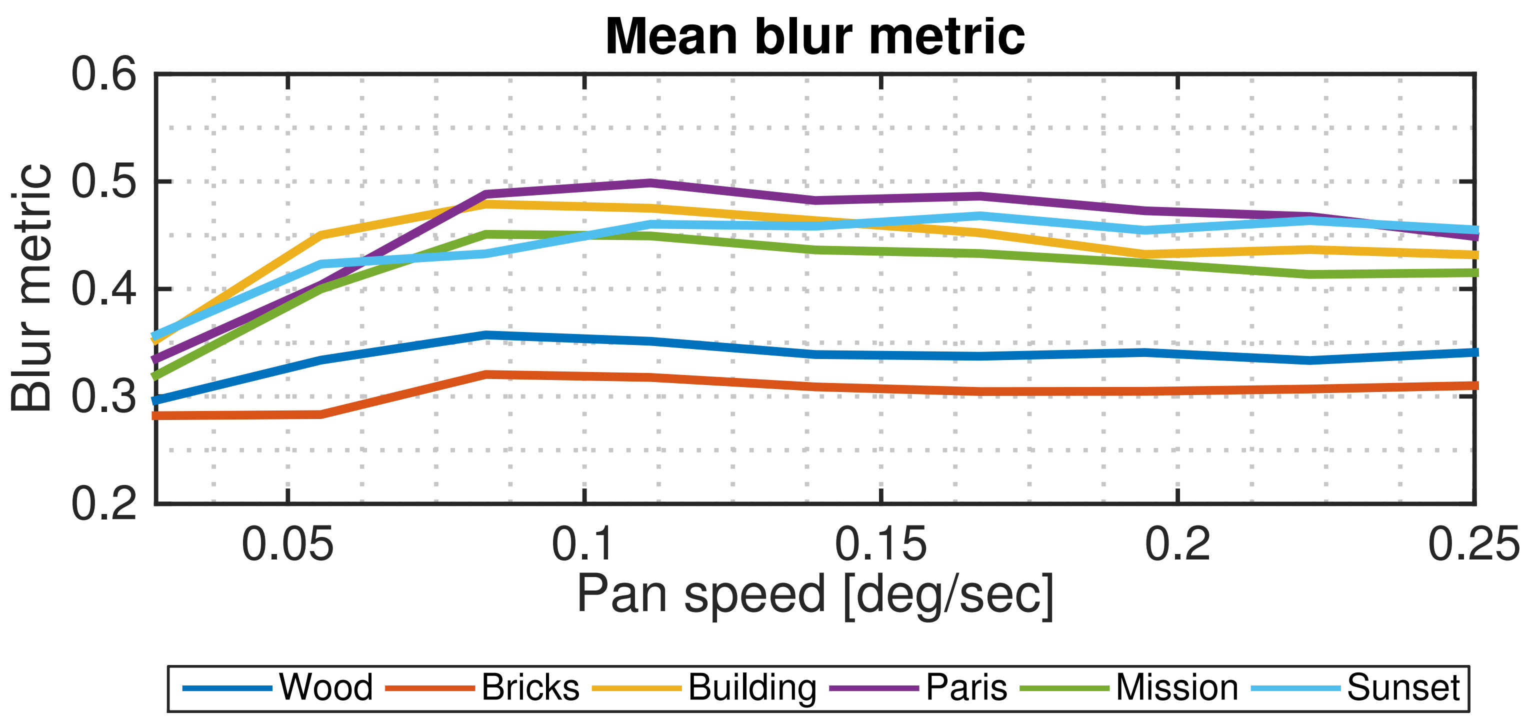
A **gyroscope** that reports angular rates could be used to predict motion blur.

However, a **vision-based blur metric** would allow motion blur detection without additional sensors.



f() → Motion Blur Score

Identifying Blur: Vision-based Blur Metric



The popular metric of Crete et al. **does not correlate well** with pan speed and varies with image texture.

F. Crete et al., “**The blur effect: Perception and estimation with a new no-reference perceptual blur metric**,” in Proc. SPIE Electron. Imaging Symp. Conf. Human Vision and Electron. Imaging, Feb. 2007

Motion Blur…

1. correlates well with rotational speed of the camera but is difficult to quantify through visual cues alone.

2. increases the variance of KLT tracking error, while preserving an approximately zero-mean Gaussian distribution.

Motion Blur…

1. correlates well with rotational speed of the camera but is difficult to quantify through visual cues alone.

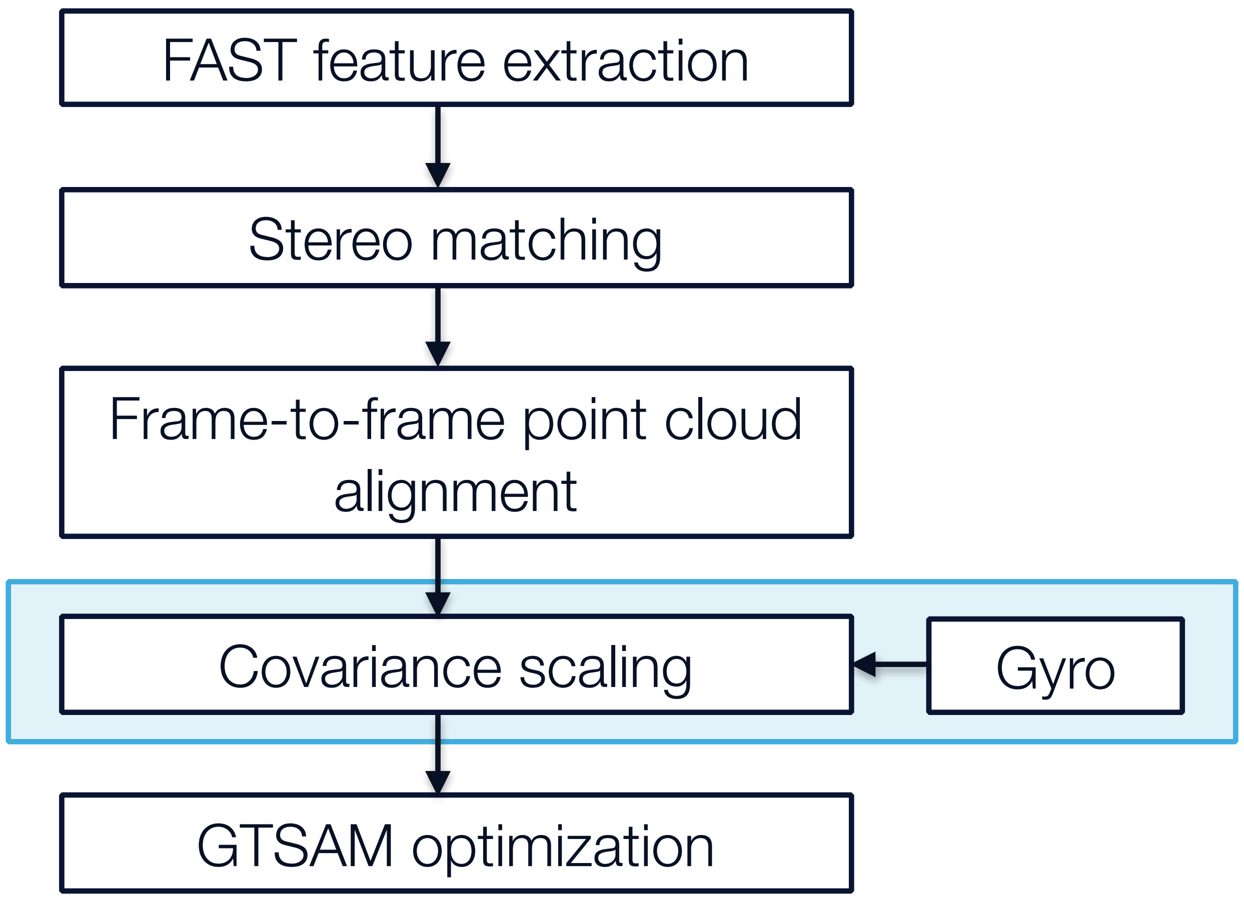
2. increases the variance of KLT tracking error, while preserving an approximately zero-mean Gaussian distribution.

?

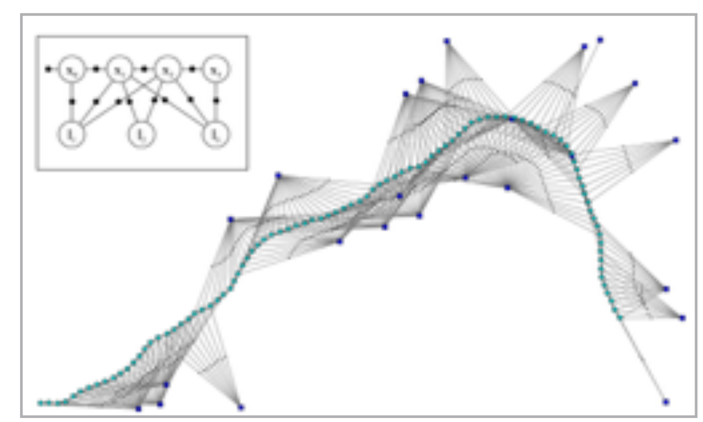
How can we use this information to **improve** our egomotion estimate?

Accounting For Blur: Stereo Visual Odometry

Idea: Use covariance scaling to improve stereo visual odometry.

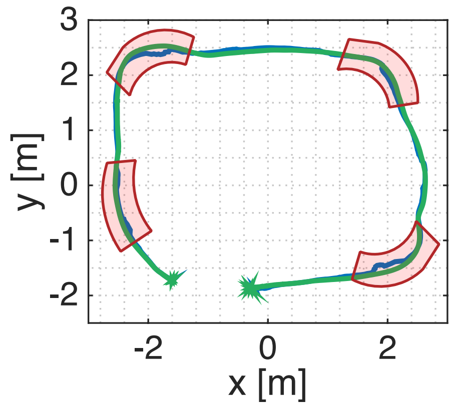


Skybotix VI-Sensor

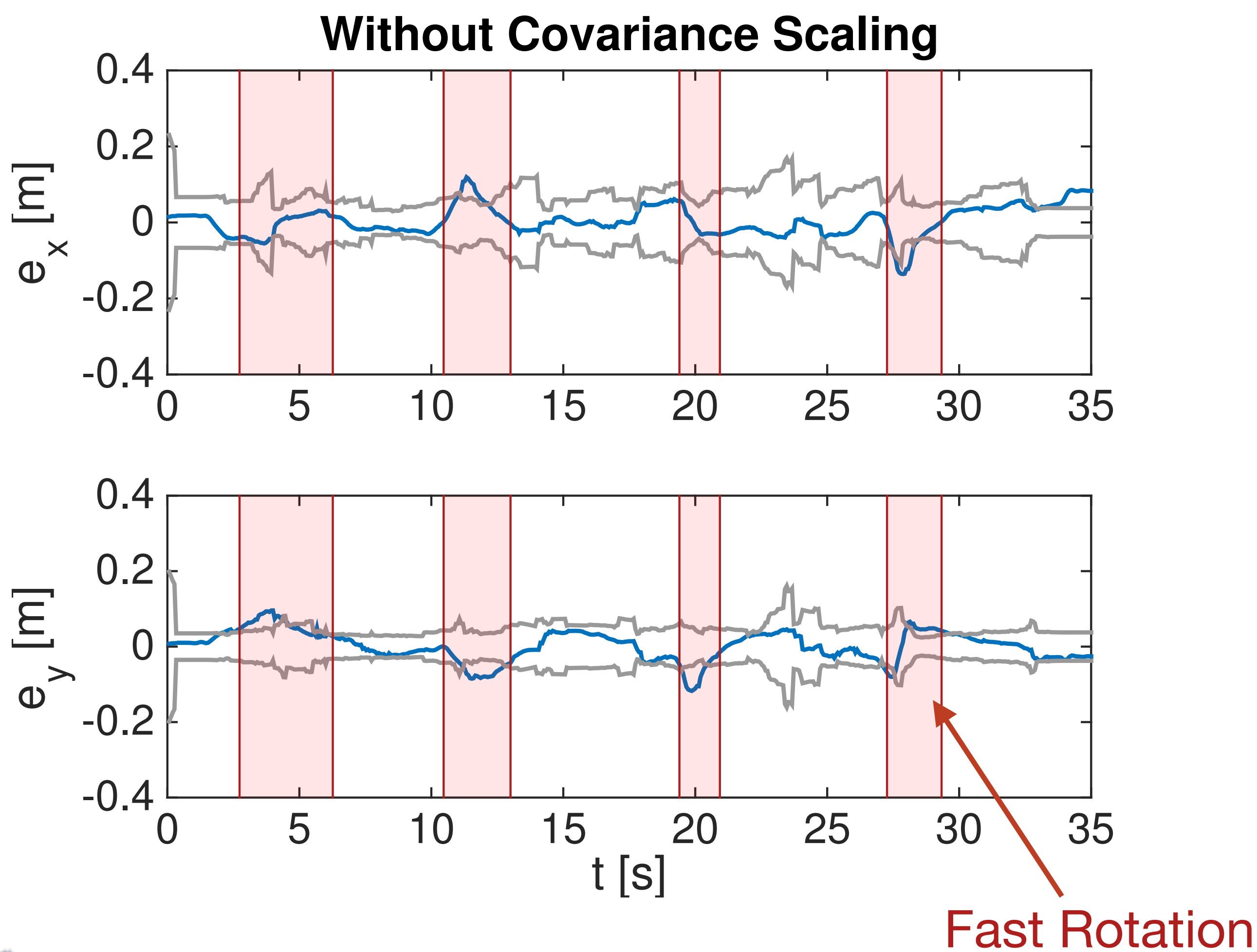


GTSAM Pose Graph

Accounting For Blur: Stereo Visual Odometry



~20 m planar route with VICON ground truth with sharp turns that induce motion blur



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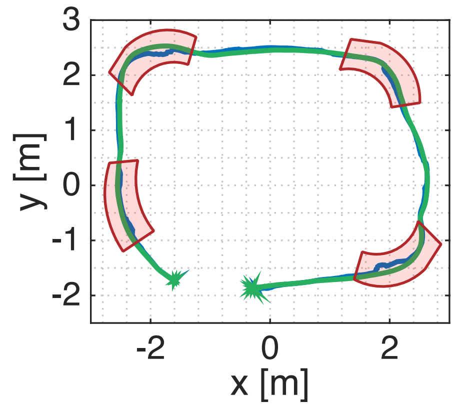
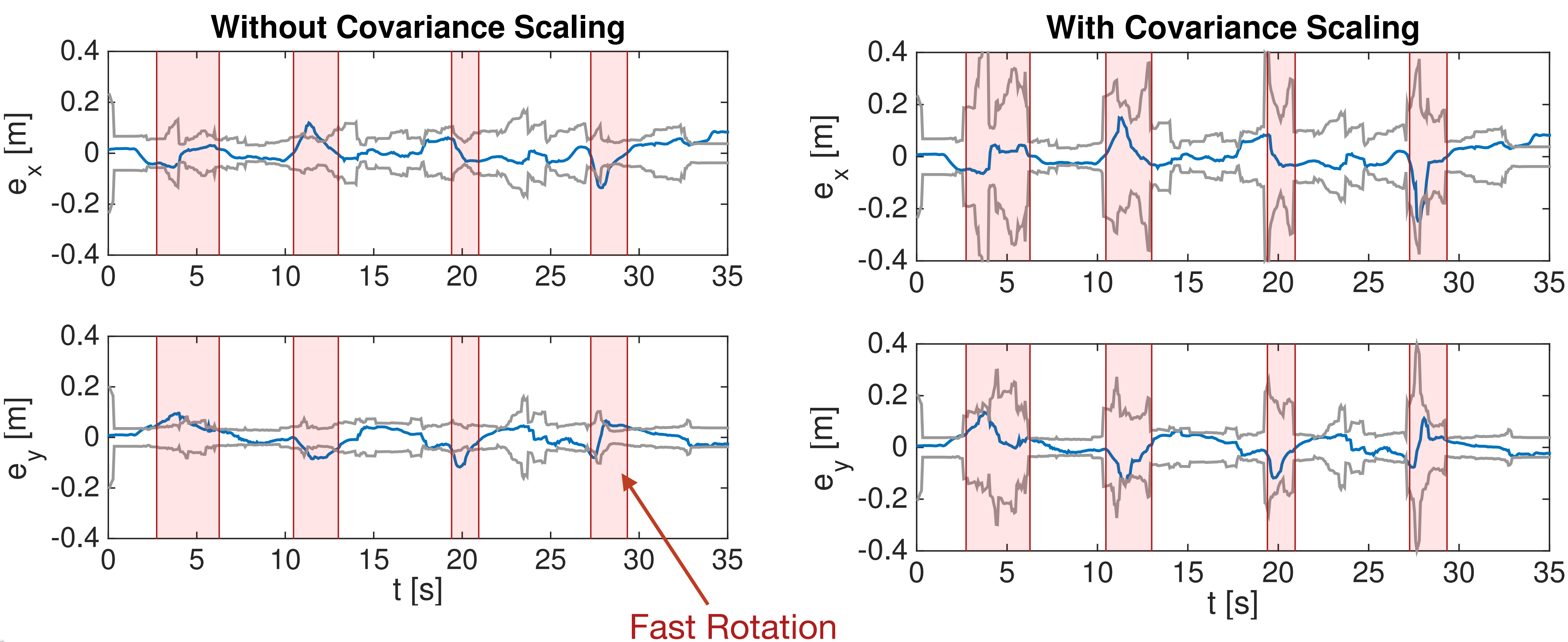
Accounting For Blur: Stereo Visual Odometry



~20 m planar route with VICON ground truth with sharp turns that induce motion blur

Estimator consistency improves with covariance scaling.



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Thanks!

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Web: http://starslab.ca