Real Time Camera Tracking: When Is High Frame-Rate Best?

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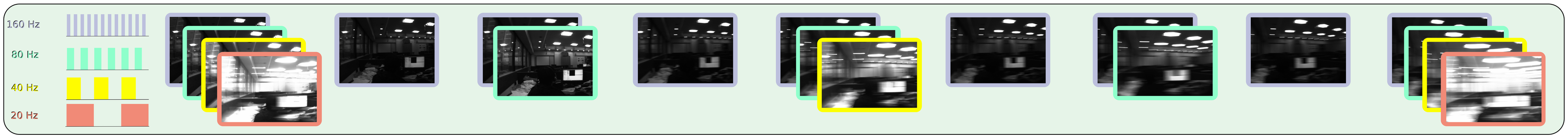
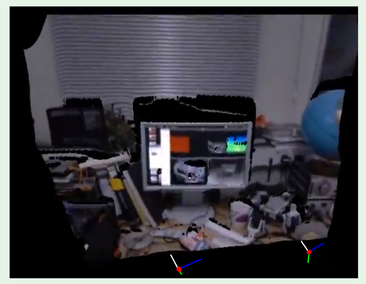
What does the same motion look like at different frame-rates? / Which frame-rate is optimal for real-time tracking?

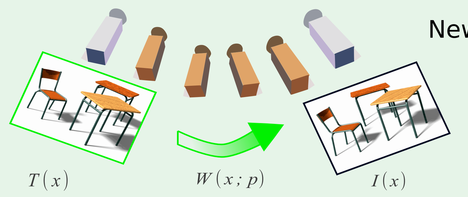


What specific tracking problem are we studying?



Newcombe et al. DTAM, ICCV2011

$T(x)$: Predicted Image
$I(x)$: Current image
p: Camera params
$W(x;p)$: Warp



Real-time 6D single camera tracking in a known 3D rigid scene using iterative whole image alignment.

What questions would we like to answer?

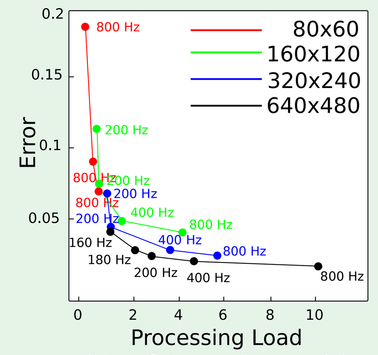
Intuitions

- High frame-rate seems better.
  Image motion is small - tracking is easy.
- Increasing image resolution is desriable.
  More data means better accuracy.

Knowing that, we'd like to find out

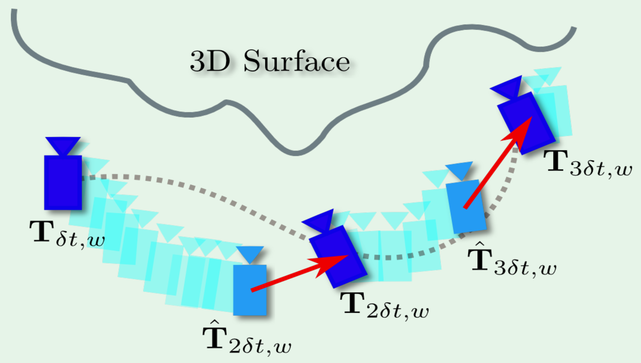
Given a limited processing budget:

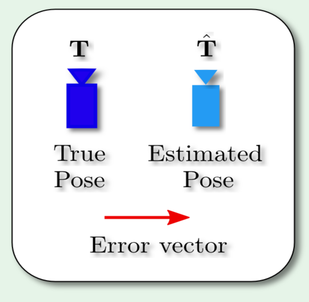
- What is the optimal frame-rate for tracking?
- What is the best image resolution for tracking?



Pareto Front of Operating Points

How do we evaluate a real-time tracker?





- **Error:** $\mathcal{L}_2$ norm of the estimated pose and ground truth pose.
- **Computational Cost:** Cost per frame $\times$ frame-rate.
- **Robustness:** how often a tracker works without gross failures.
  Not analyzed in this paper but plan to work on it in future.

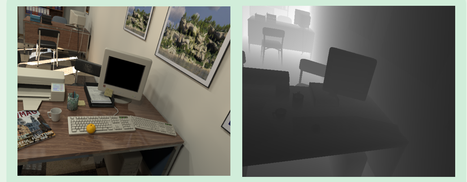
How do we gather experimental data?

Collecting Real Data

- ✗ Not easy to obtain ground truth.
- ✗ Not easy to have repeatable camera trajectory.
- ✗ Cannot obtain resolution other than standard resolutions.
- ✗ Cannot control scene lighting.

Justification for synthetic framework for obtaining data

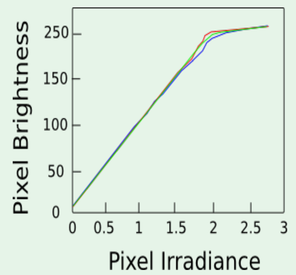
- ✓ Can exercise full control of parameters
- ✓ Perfect ground truth.
- ✓ Repeatable camera motion
- ✓ Controlled scene lighting



POVRay raytraced image and depth-map

How to add photo-realism in synthetic images?

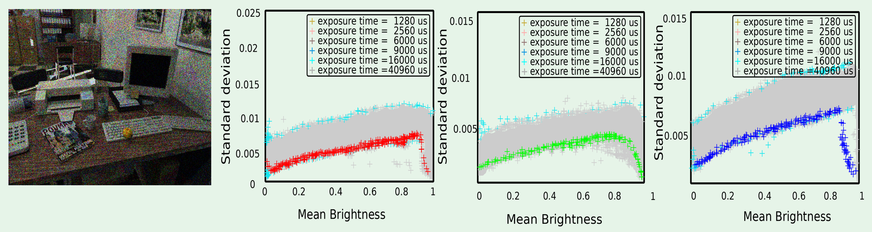
How do we create motion blur?



Calibrating Camera Response Function

- Obtain pixel Irradiance to brightness map of camera.
  Camera Response Function (CRF)
- Use the CRF to map brightness for synthetic images.
  POVRay gives Irradiance.

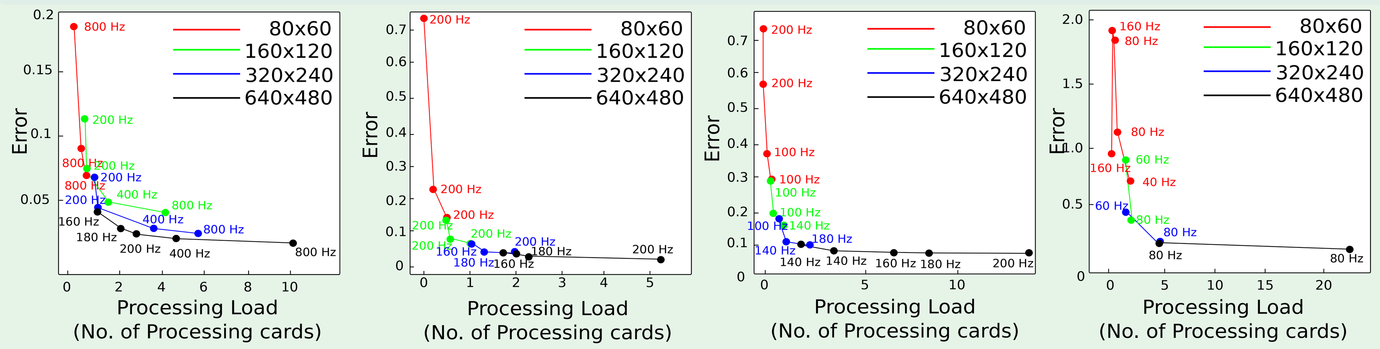
How do we add camera noise?



Calibrating Camera Noise Level Function

- Take multiple shots of static scene with varying shutter times.
- Plot mean brightness of pixel against the standard deviation.
- Fit a parametric function to obtain the noise level for all channels.
- Use this noise in the synthetic images for all frame-rates.

What are our conclusions and results? / What do we interpret from the data?



Perfect Lighting	High Lighting	Moderate Lighting	Low Lighting
No noise and no motion blur	$\alpha = 40$	$\alpha = 10$	$\alpha = 1$

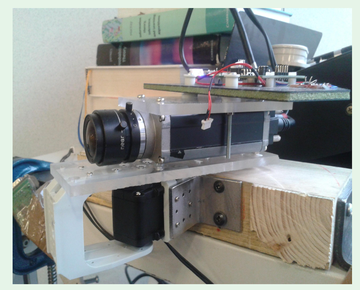
Perfect Lighting: Use the combination of highest possible frame-rate and resolution the budget allows.

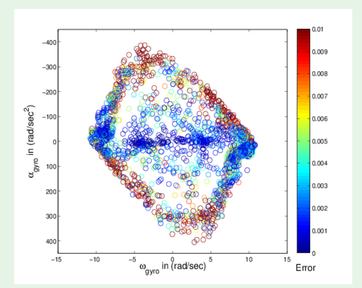
Real Lighting: There is optimal frame-rate that depends on scene lighting.

- High lighting allows high SNR images and therefore optimal frame-rate is high e.g. 200Hz
- Moderate Lighting means optimal frame-rate shifts to a lower value e.g. 100-140Hz
- Low Lighting permits working on only low frame-rates - high frame-rate images are dark and noisy.

Future goals and directions

Real Experiments





- Verify the conclusions from synthetic framework.
- Obtain the robustness curves for all frame-rates.
- Find out answers to more questions e.g.

If camera is moving with a known acceleration and velocity, what is the optimal frame-rate taking accuracy, cost, and now robustness into account?

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