Rolling Shutter and Radial Distortion are Features for High Frame-Rate Multi-Camera Tracking

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

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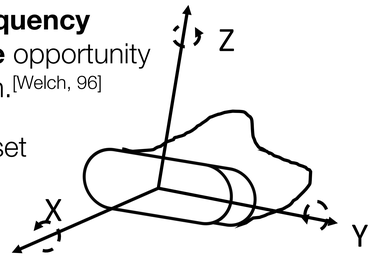
Overview



Motivation: Tracking **frequency** determines **first possible** opportunity to respond to user motion.[Welch, 96]

Goal: Track VR/AR headset as fast as possible using sensors on the headgear.

Challenges:

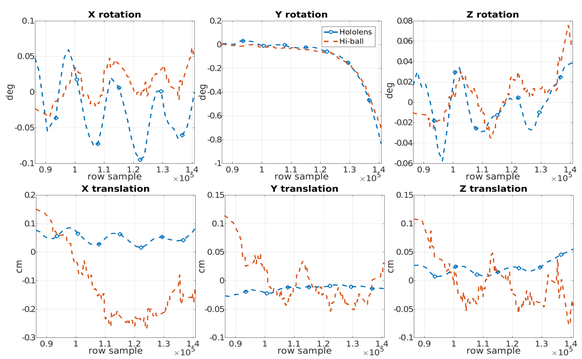
1. **Fastest human motion** is 700°/s neck rotation; normal rotation is 70°/s; walking is ~1.4m/s.[Bishop, 84]
2. **Motion-sickness** is quickly induced if imagery does not match head motion.
3. **Camera frame-rate, exposure time, and the number of cameras** hinder high-frequency inside-out tracking.

Contributions:

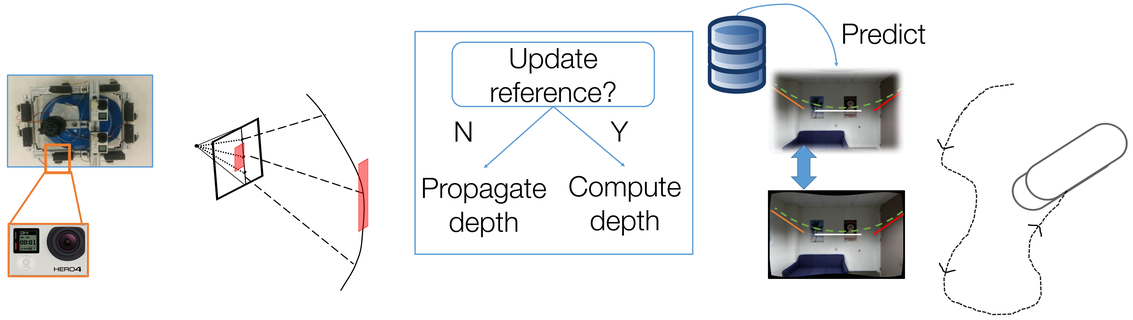
- **Tracking frequency = fps*height** = 86.4kHz
- System uses commodity rolling shutter cameras.
- We convert rolling shutter and radial distortion artifacts into virtues for tracking.
- Supports 4- and 6-camera designs with arbitrary camera orientations.

High-frequency tracking is hard

HoloLens tracking compared to ground truth



Method



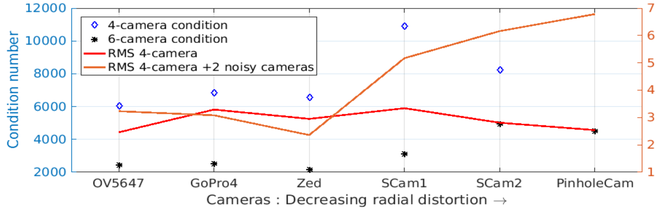
Rolling Shutter and Radial Distortion

1. **Rolling shutter capture**: Row-wise (or column) sequential exposure of image.
   - Rapid motion induces warps and wobbles under rolling shutter capture.

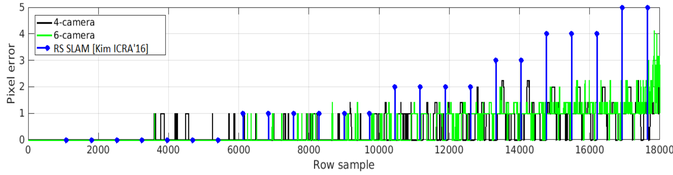
2. **Radial distortion**: Lens distortion maps straight lines in world to curves in image. Inversely, rays of a row in rolling shutter camera span a curve in the world.
3. **Linear segment approximation**: Treat a distorted row as multiple linear segments captured by different virtual rolling shutter cameras.

Results

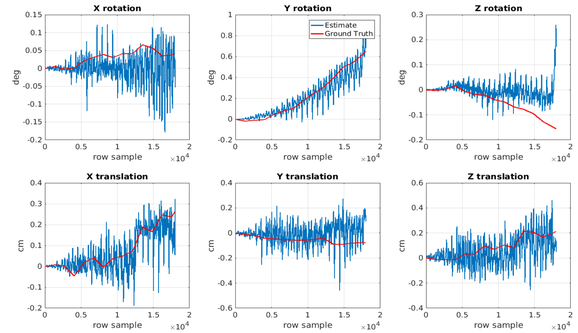
Higher radial distortion increases system stability



4-camera cluster drifts faster than 6 cameras
The errors are smaller than RS-SLAM [Kim ICRA'16]



4-camera results on real-world data



RMS	Tx (cm)	Ty (cm)	Tz (cm)	θx (deg)	θy (deg)	θz (deg)	Render (px)
4-camera real data	0.0648	0.0974	0.1064	0.0541	0.0776	0.072	0.6804
6-camera real data	0.1783	0.0890	0.1139	0.0326	0.0499	0.0959	0.7507
HoloLens	0.21	0.04	0.05	0.05	0.03	0.02	0.8249
4-camera synthetic	0.43	0.18	0.23	0.14	0.23	0.06	2.55
6-camera synthetic	0.38	0.27	0.22	0.13	0.22	0.08	2.39
20-cam [Bapat'16]	0.67	0.83	1.34	0.21	0.47	0.29	4.63

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