Performance Measurements of Virtual Reality Systems: Quantifying the Timing and Positioning Accuracy

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Motivation

- Commodity VR systems are usually with limited accessibility of hardware and software
- Existing methods are hard to generalize because they require code instruments or assuming the existence of a specific virtual object
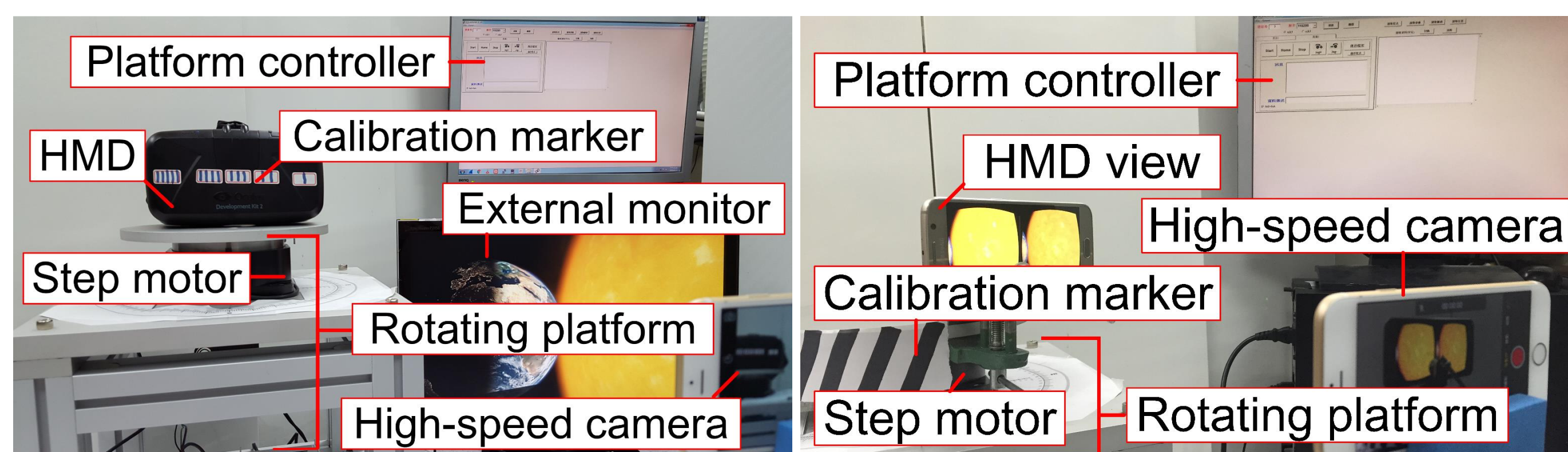- The performance of VR systems has not been discussed in aspect of timing and positioning accuracy in the literature

Considered VR Systems

Type	Desktop VR Systems		Mobile VR Systems†	
Brand	3Glasses D2 (3GD2)	Oculus Rift DK2 (ORDK2)	Google Cardboard (GC)	Samsung Gear VR (SGVR)
FoV (^{o})	110	100	96	96
Display	2560 x 1440 60Hz	2560 x 1440 75 Hz	2560 x 1440 60 Hz	
CPU	Intel i7-4790 CPU 3.6 GHz		4-core Cortex-A57 2.1 GHz and 4-core Cortex-A53 1.5 GHz	
GPU	NVIDIA GeForce GTX 645		Mali-T760 MP8	
RAM	32 GB		3 GB	

† Samsung S6 is used in mobile VR systems

Measurement Testbed

- A rotating platform to emulate head (HMD) movements
- An external display that mirrors the view in the HMD
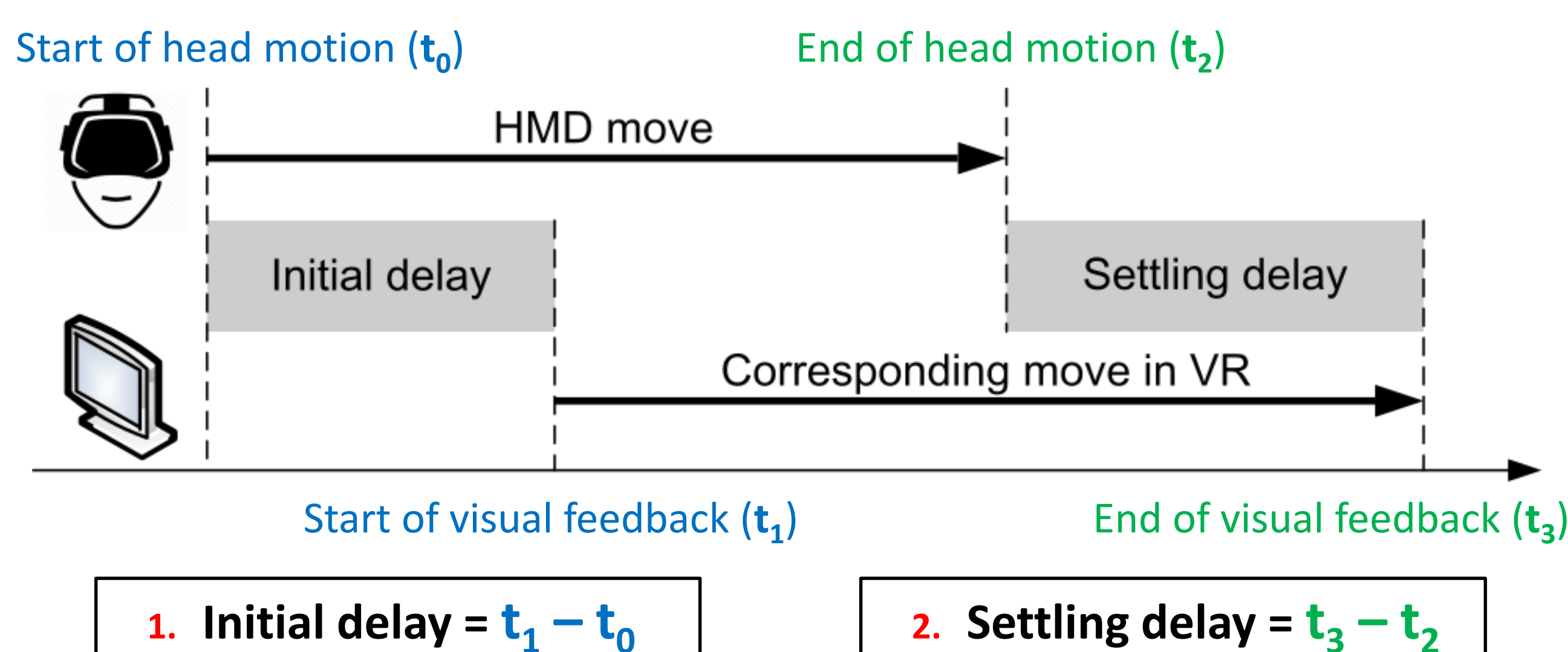- A high-speed camera that captures the HMD device and its view
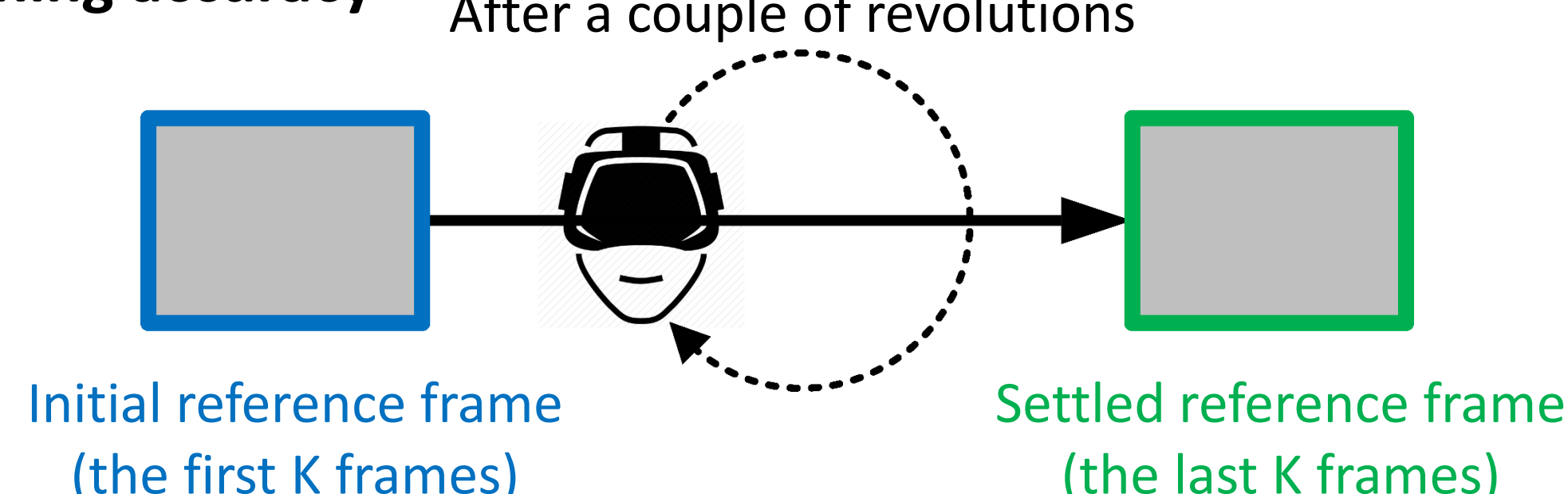

(a) With Oculus Rift DK2   (a) With Google Cardboard

Performance Metrics

- **Timing accuracy**

Start of head motion (t_0)   End of head motion (t_2)
HMD move
Initial delay   Settling delay
Corresponding move in VR
Start of visual feedback (t_1)   End of visual feedback (t_3)

1. **Initial delay** = $t_1 - t_0$
2. **Settling delay** = $t_3 - t_2$

- **Positioning accuracy**

After a couple of revolutions

Initial reference frame (the first K frames)   Settled reference frame (the last K frames)

3. **Precision** = Percentage of pixels *changed* between initial reference frame and settled reference frame; where a pixel is *changed* if its gray-level difference greater than 30

After a subtle motion
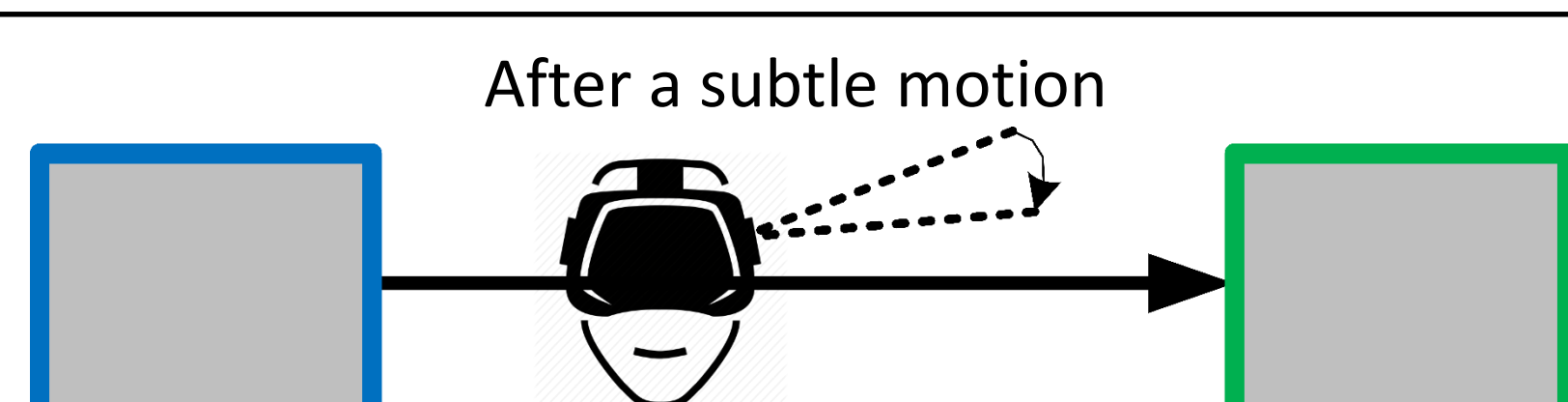
4. **Sensitivity** = Ratio of *sensible rounds* in all the rounds; where a round is considered as *sensible* if found any changed pixels

Methodology

Record in 240 fps   Clip by motions   Define two regions
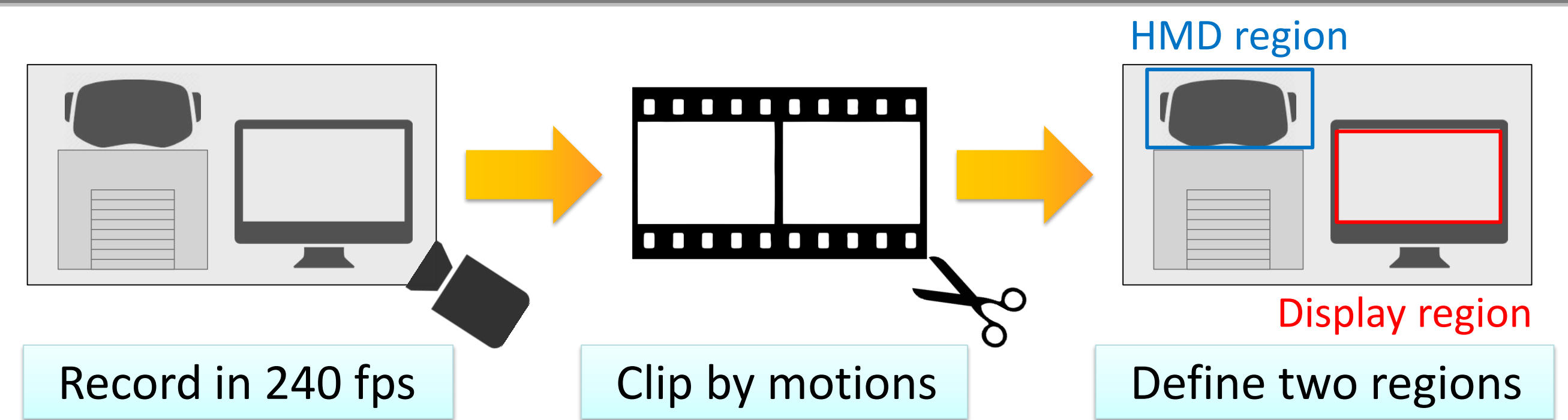
Compute region change ratio in percentage of the changed pixels in each region compared with the reference frame

Apply the change point detection algorithm to identify:
1. t_0 and t_1 based on initial reference frame
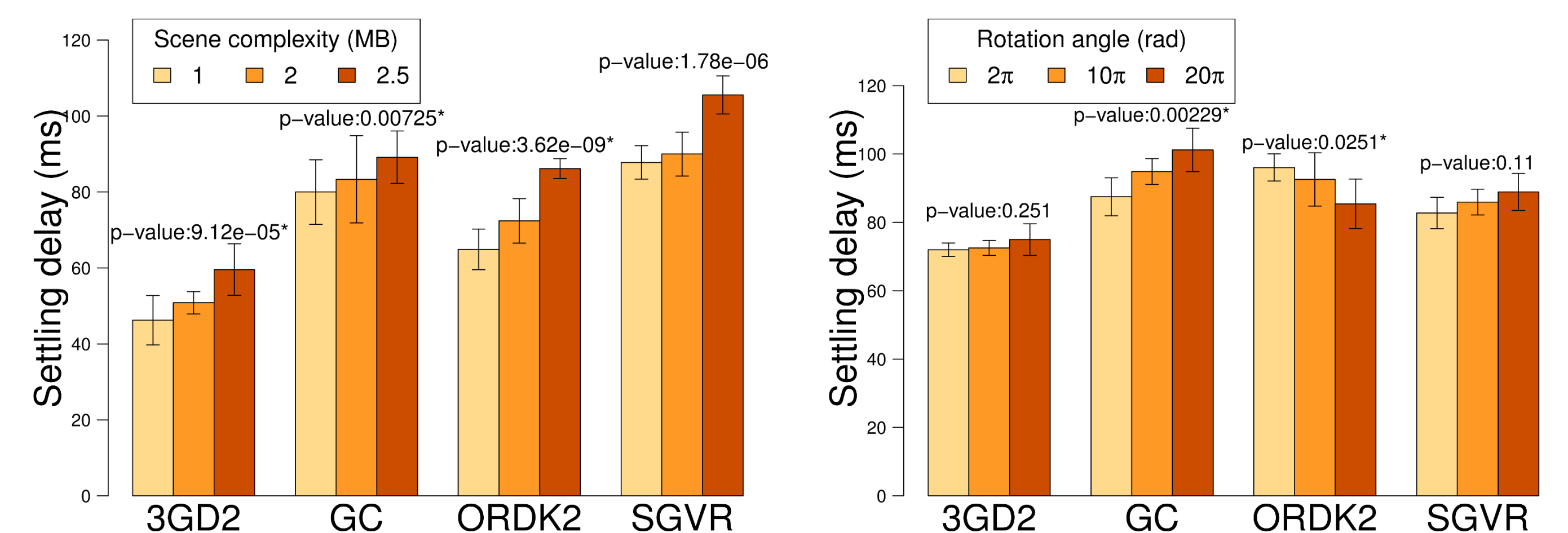2. t_2 and t_3 based on settled reference frame
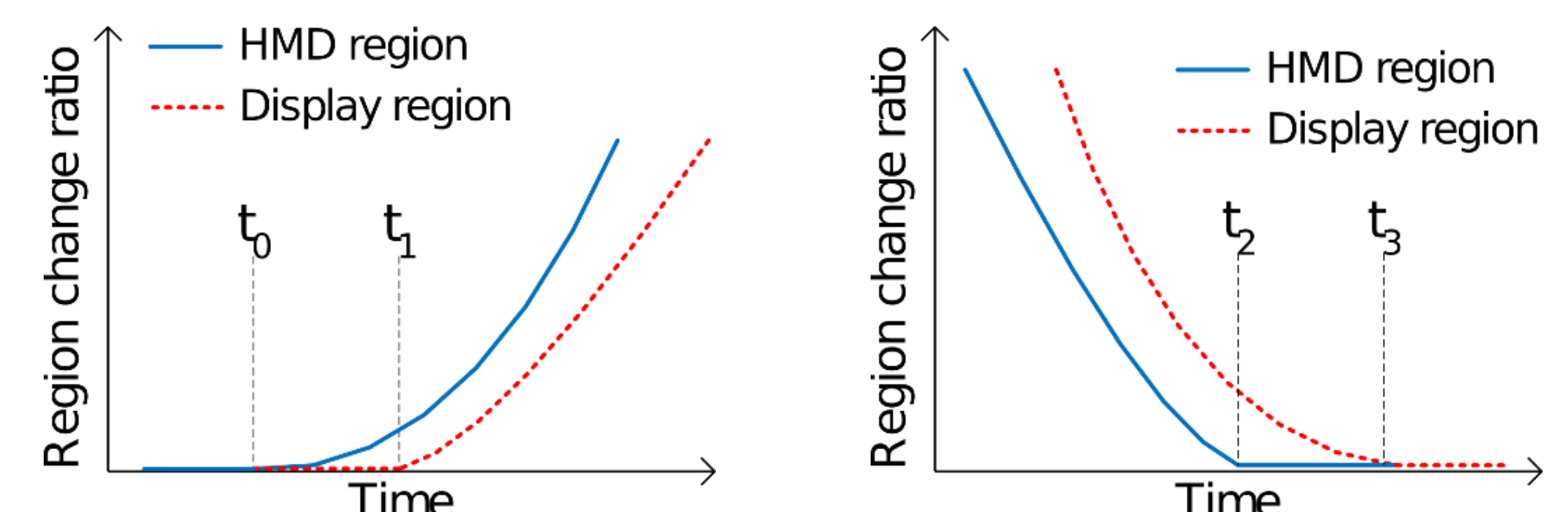
- With the above timestamps, initial and settling delays are easily obtained
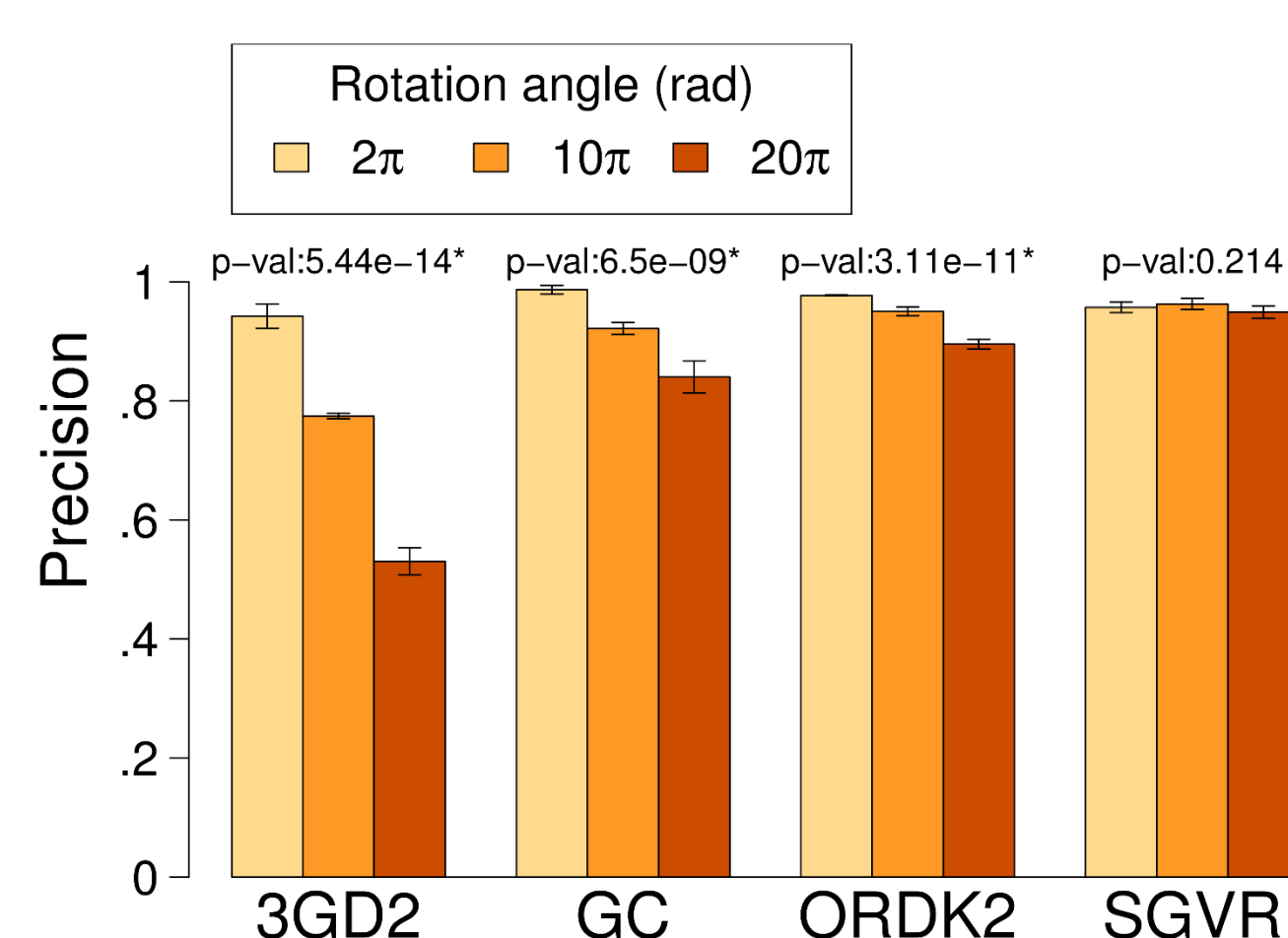- Precision and sensitivity can be measured with both initial and settled reference frames

Experiment Results

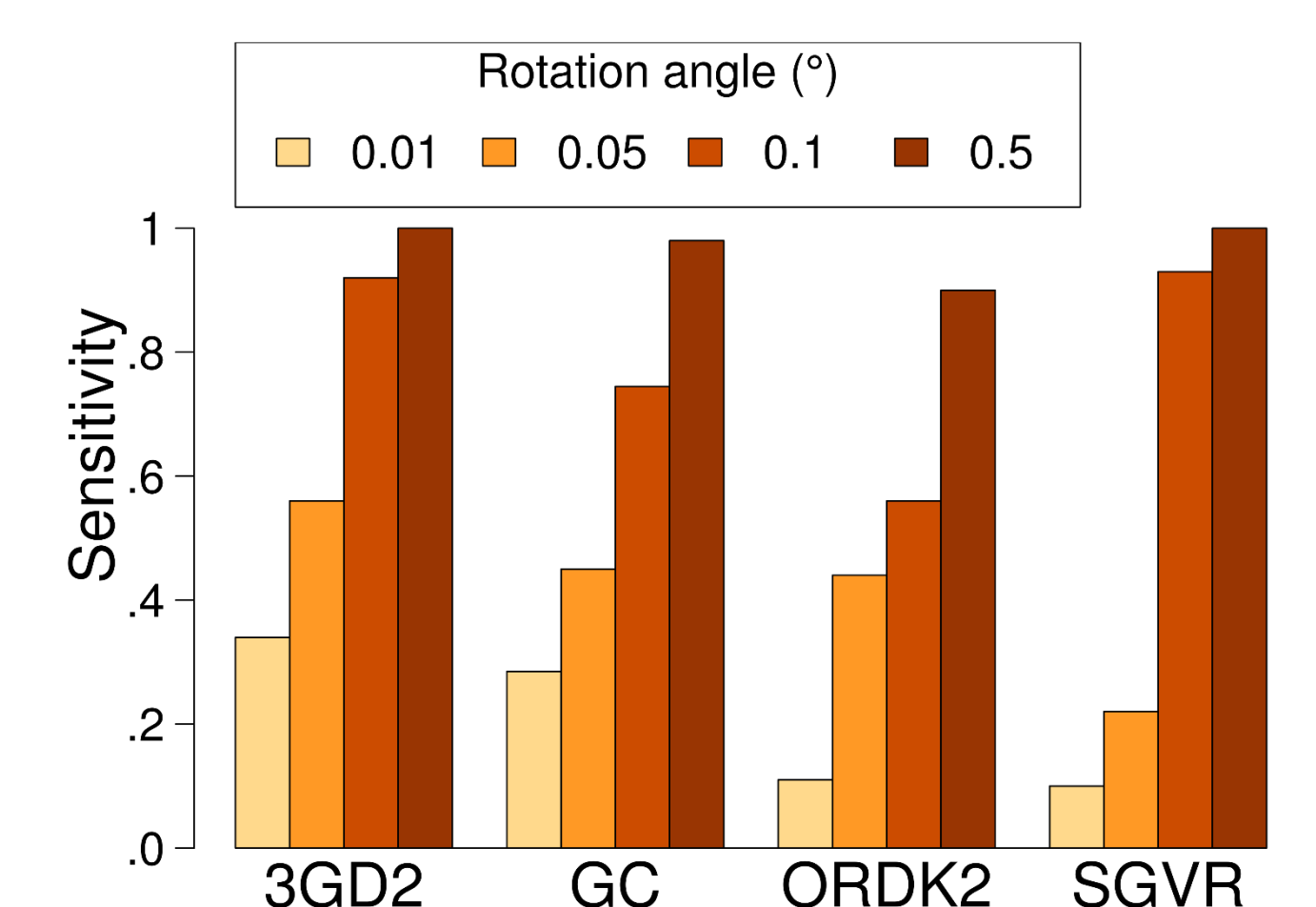- **Default setting: angle=90⁰, velocity=180⁰/s; APP: Titans of Space (v1.8)**
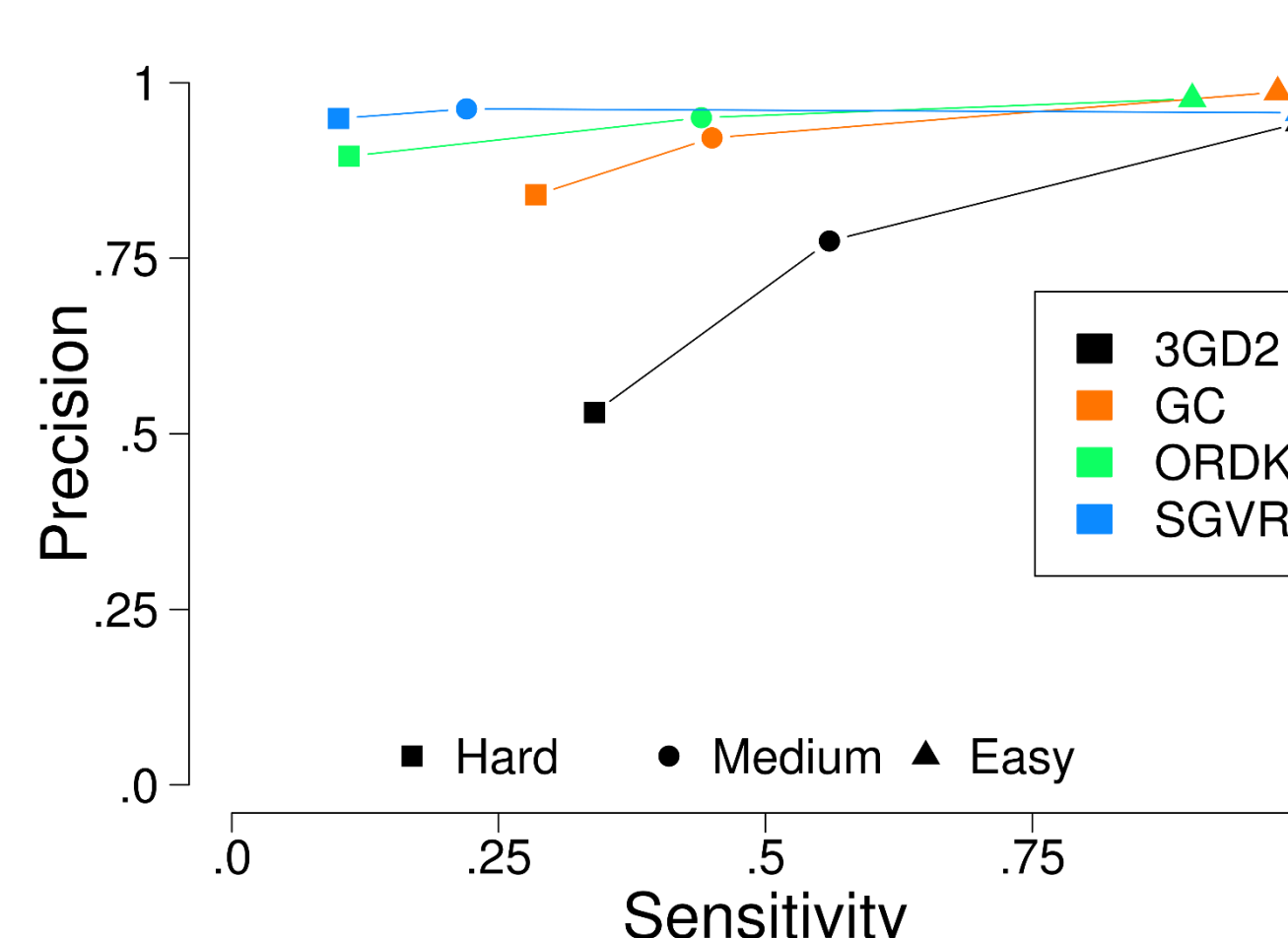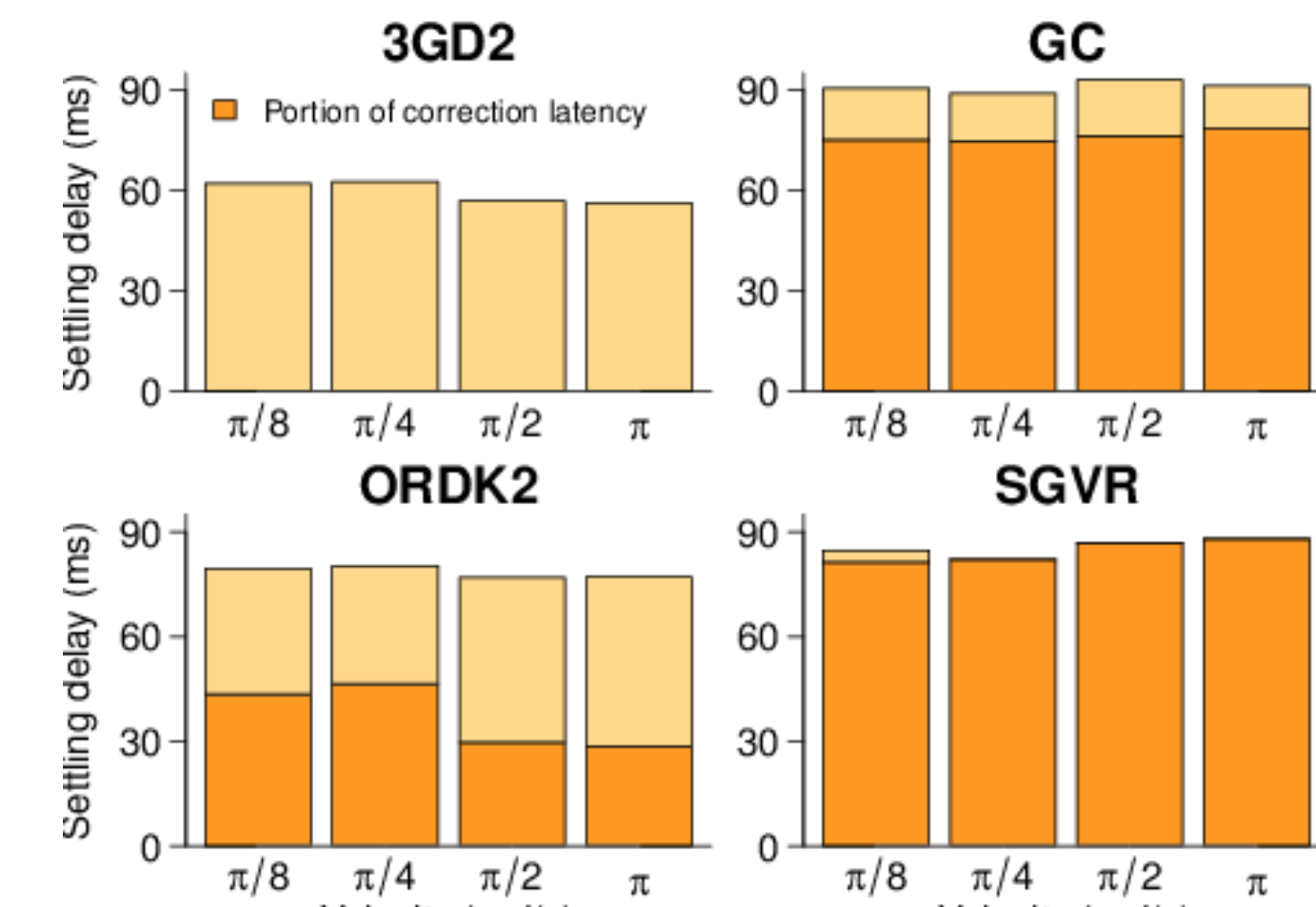- Timing accuracy

- Precision
- Sensitivity

- Trade-off in positioning accuracy
- Correction effect while settling

Conclusion

- We proposed a system-wide measurement methodology to quantify the timing and positioning accuracy
- Our methodology is generalizable to any applications without code instruments and system modification

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