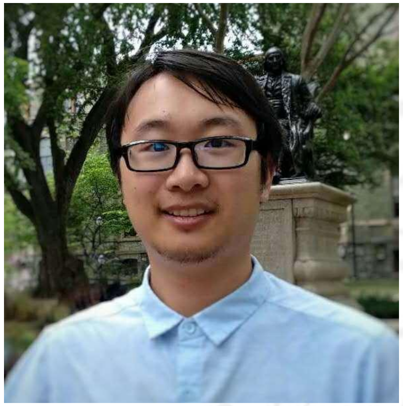
Reality Check: A Tool to Evaluate Spatial Inconsistency in Augmented Reality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Presentation Overview:

1. AR Background
2. Problem
3. Method
4. Method Background
5. Experiments Setup
6. Results
7. Acknowledgements

What Is Mobile Augmented Reality?

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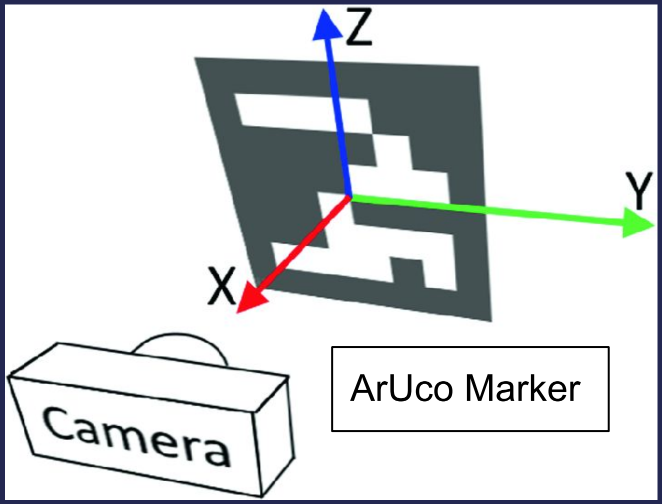
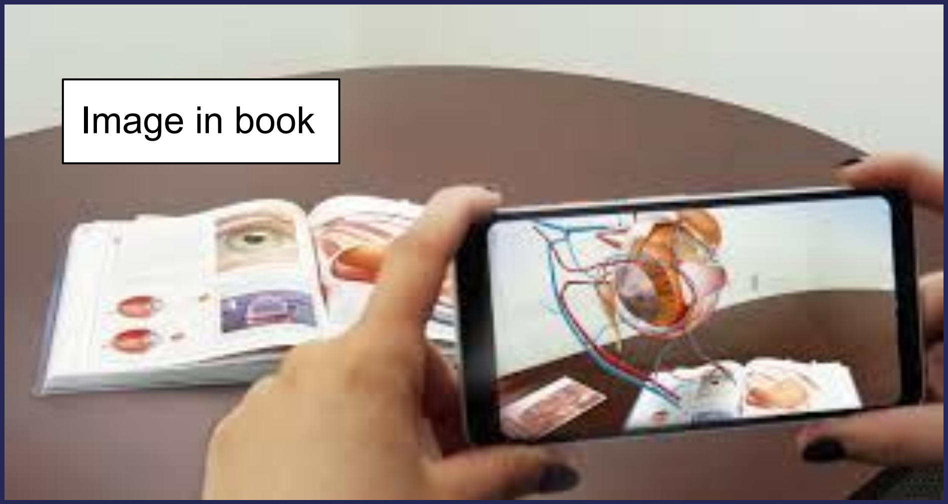
Overlaying real scene, captured by a mobile camera, with virtual objects in such a way as to appear in the real world

- Requires “understanding” the real world
- Typically needs to be done in real time
- Multiple methods
- On mobile devices, usually rely on one RGB camera and a low quality Inertial Measurement Unit (IMU)

Marker Based AR Methods

Device looks for known fiducial markers from the camera image in order to gain pose and scene understanding





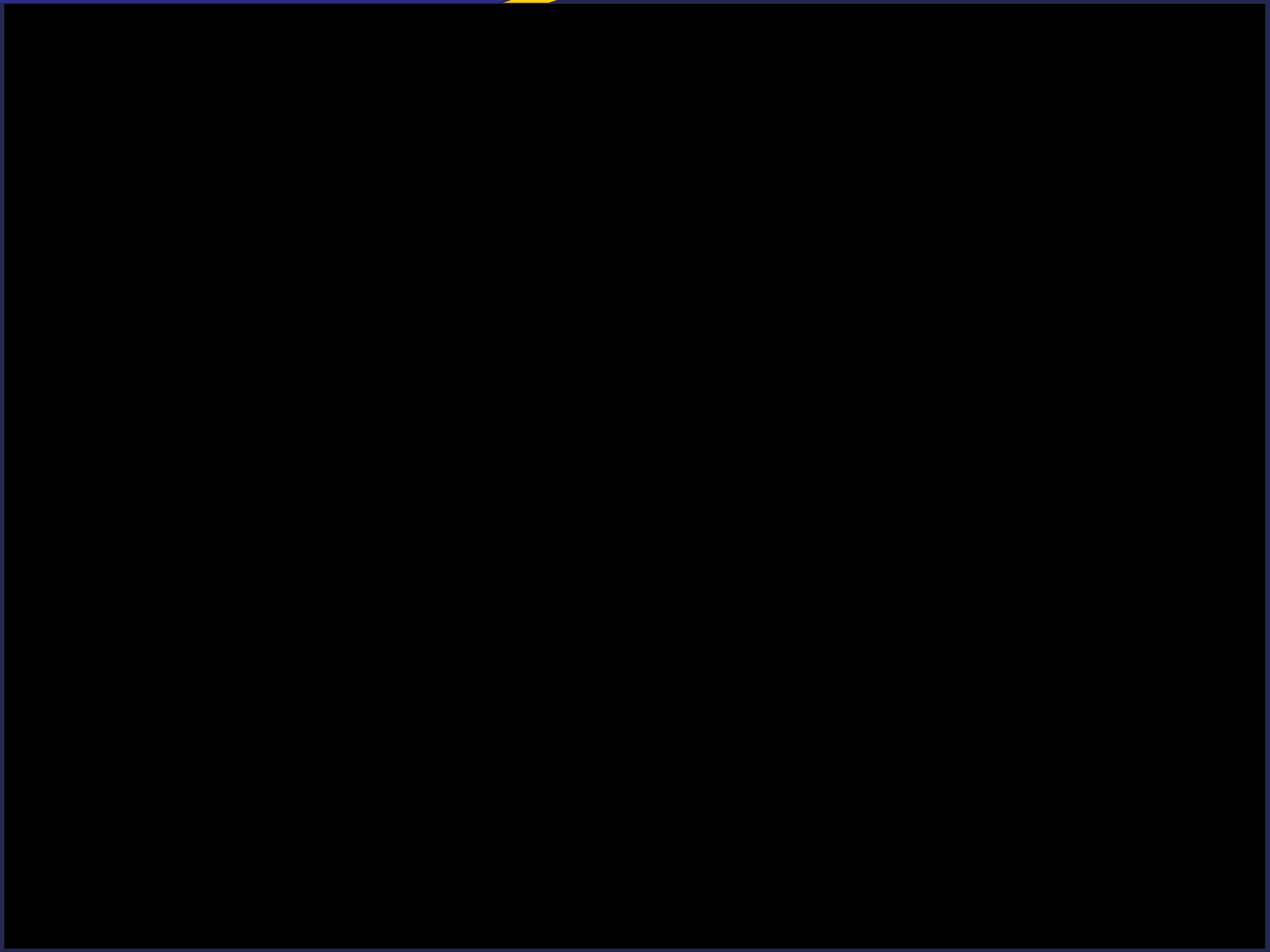
- Requires physical alteration of the scene
- Marker must remain visible for the whole session
- Highly accurate, not prone to jumps and drift

Marker-less AR Methods

Track image features over time to simultaneously map the surrounding scene and localize the camera within it.

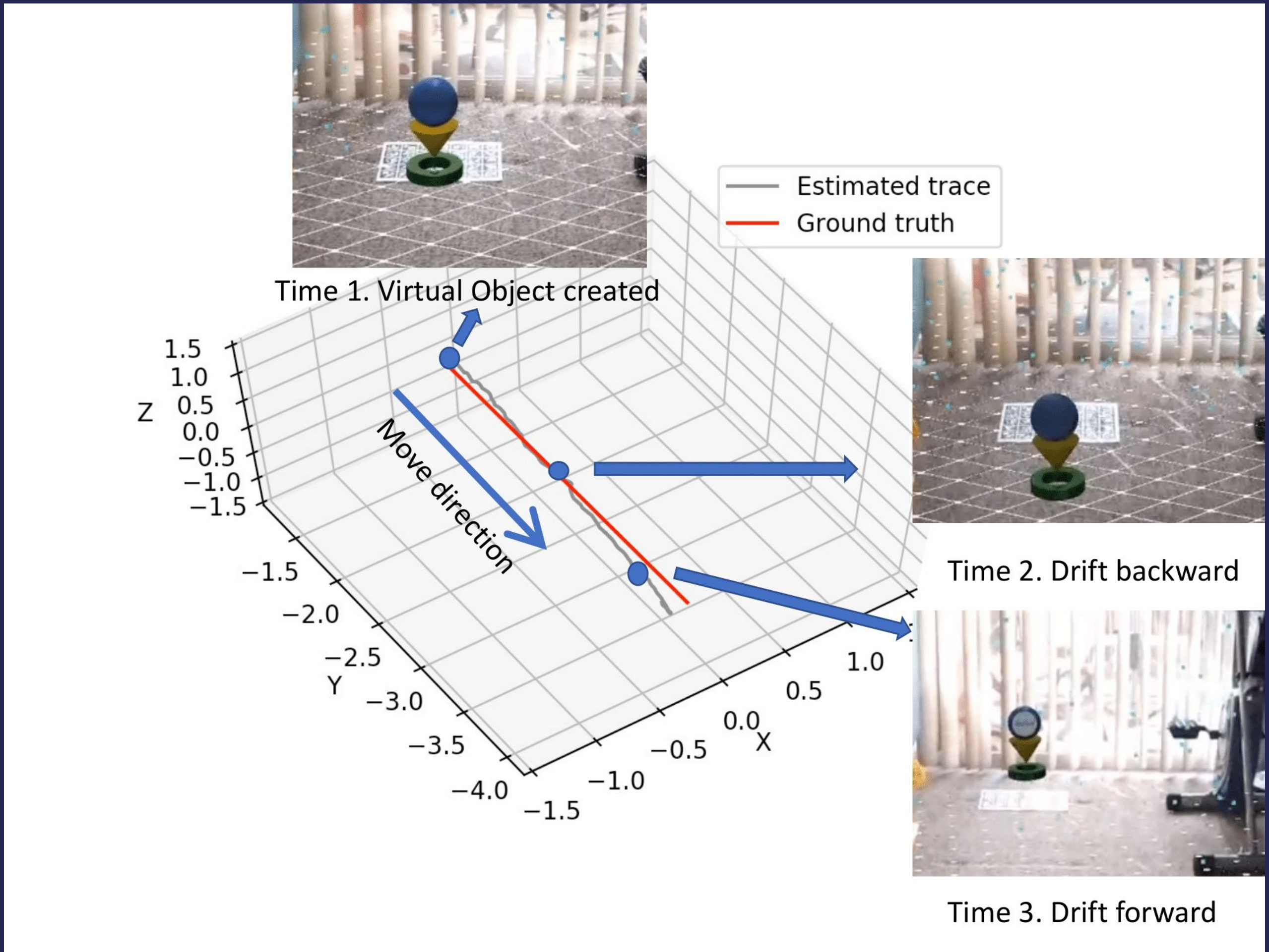
- No need for prior knowledge or alteration of scene
- Less accurate and prone to drift/jumping virtual objects

The Problem



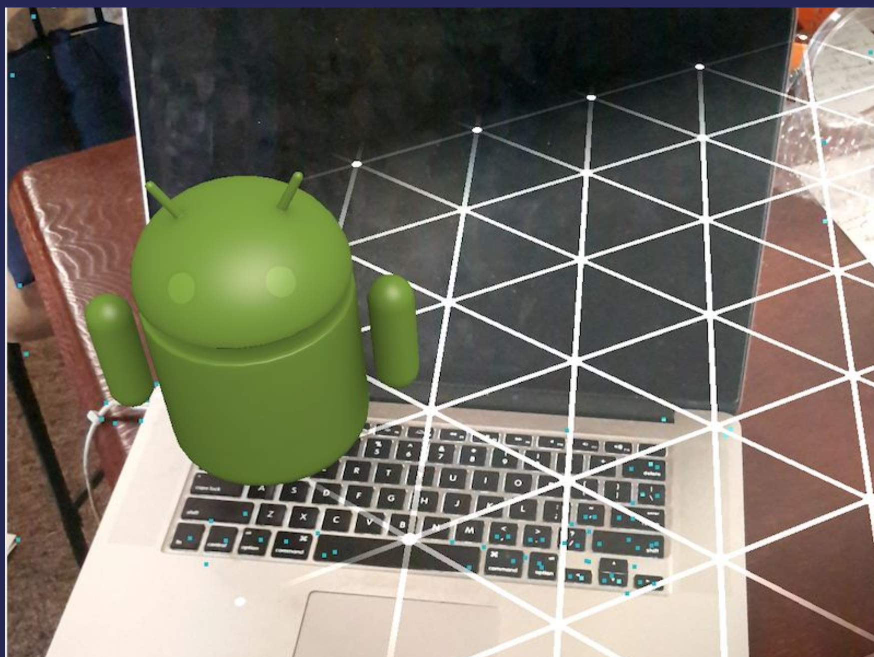
How do we measure the drift of virtual objects in a way that is neither expensive nor labor intensive?

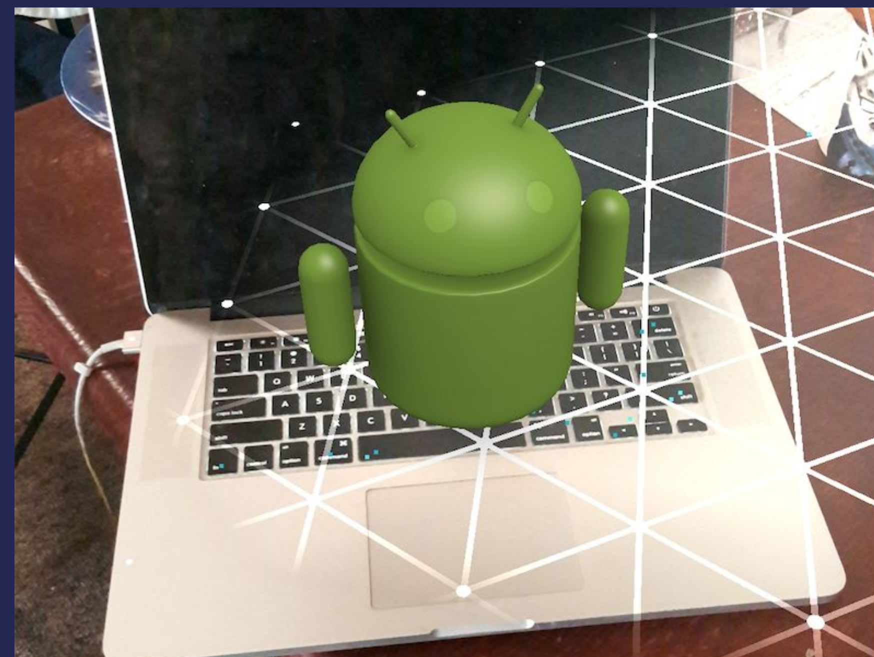
The Problem



Absolute Trajectory Error (ATE) is not sufficient! Must take into account ALL factors that affect the final Image

The Problem



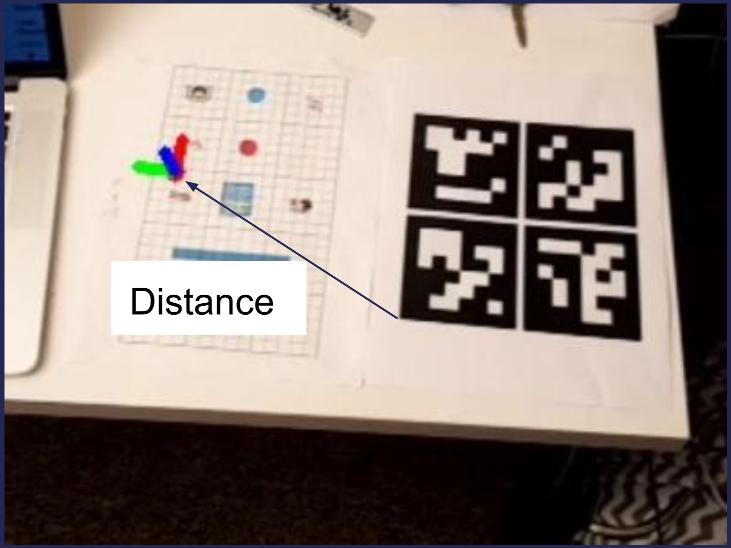


The same object viewed from two devices at the same time may also suffer from spatial inconsistency

High Level Idea:

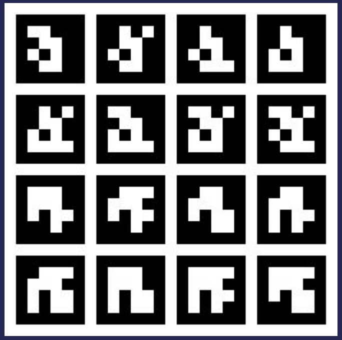
Key idea: Use easy to detect, known markers in the scene to measure spatial inconsistency.

Compare distance to marker over time or across devices to measure spatial inconsistency

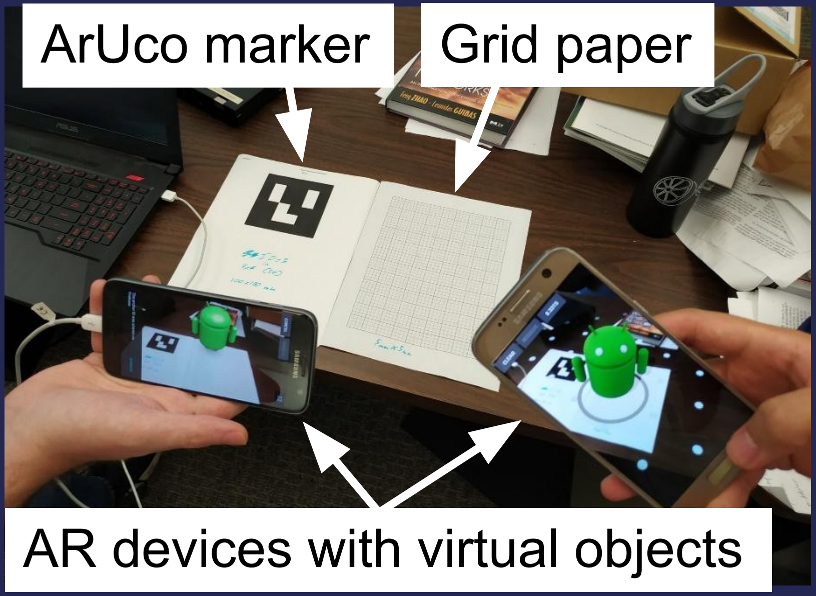


Method Background: ArUco Marker Board

ArUco: 2D square representations of binary matrices.



Our setup in the lab:



Known image and size

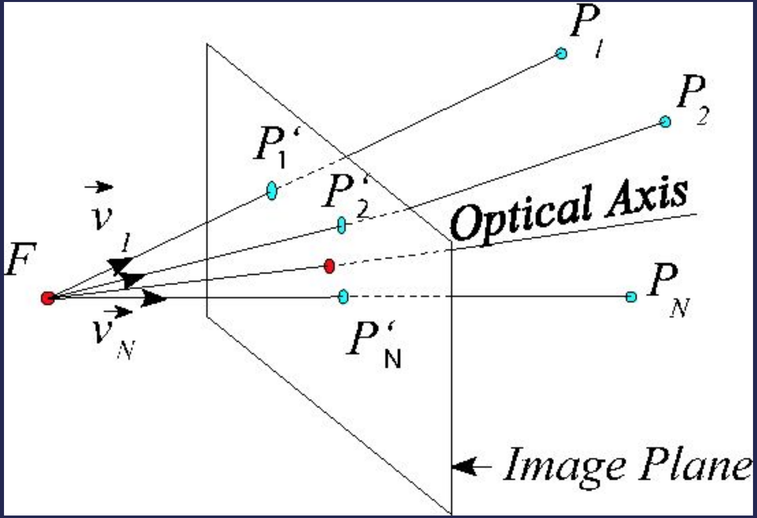
Easy to detect in images

Used to find correspondences between real world points and their projection to the 2D AR display.

Method Background: Perspective-n-Point

PnP solves for the pose (rotation, translation) of the camera relative to the detected ArUco marker board.

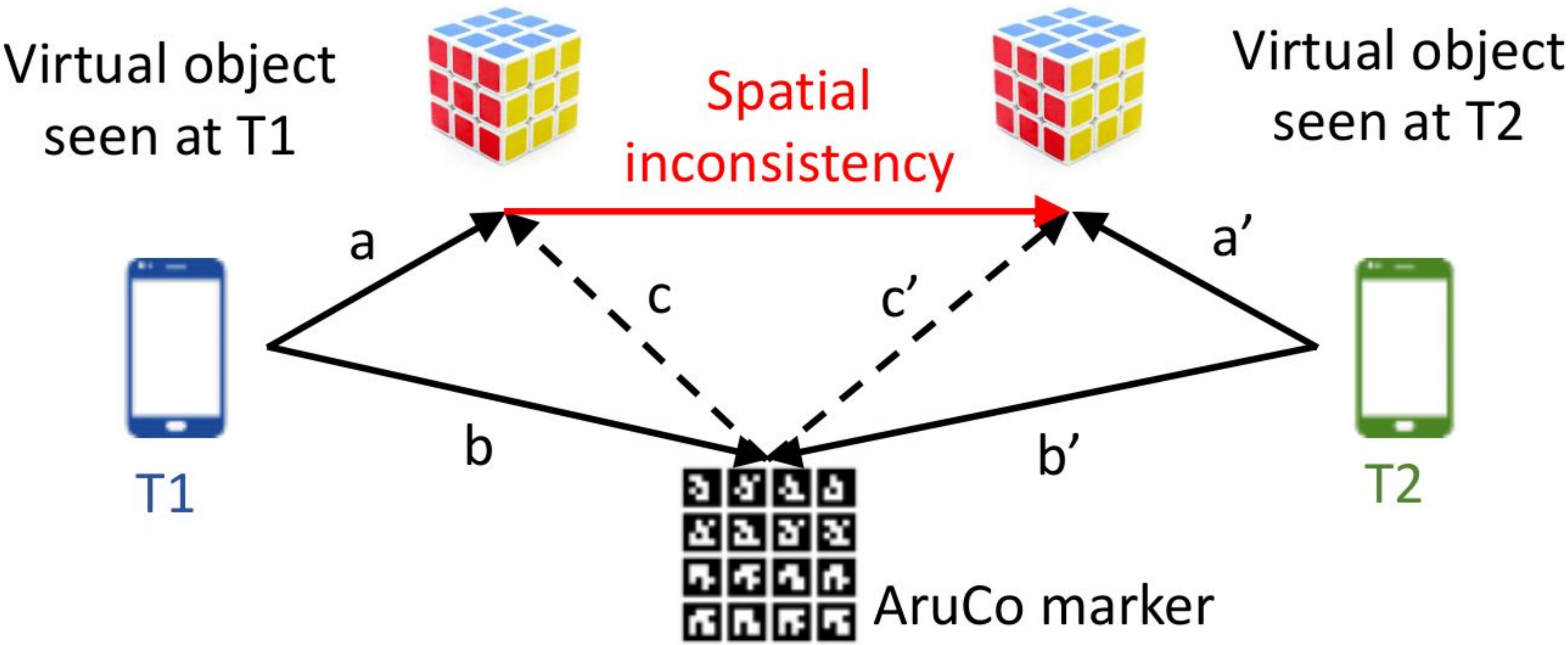
Fabrizio et al ->



Solve for r,t given many P(x,y,z) → P'(u,v) correspondances

$$s\begin{bmatrix}u\\v\\1\end{bmatrix}=\begin{bmatrix}f_x & \gamma & u_0\\0 & f_y & v_0\\0 & 0 & 1\end{bmatrix}\begin{bmatrix}r_{11} & r_{12} & r_{13} & t_1\\r_{21} & r_{22} & r_{23} & t_2\\r_{31} & r_{32} & r_{33} & t_3\end{bmatrix}\begin{bmatrix}x\\y\\z\\1\end{bmatrix}$$

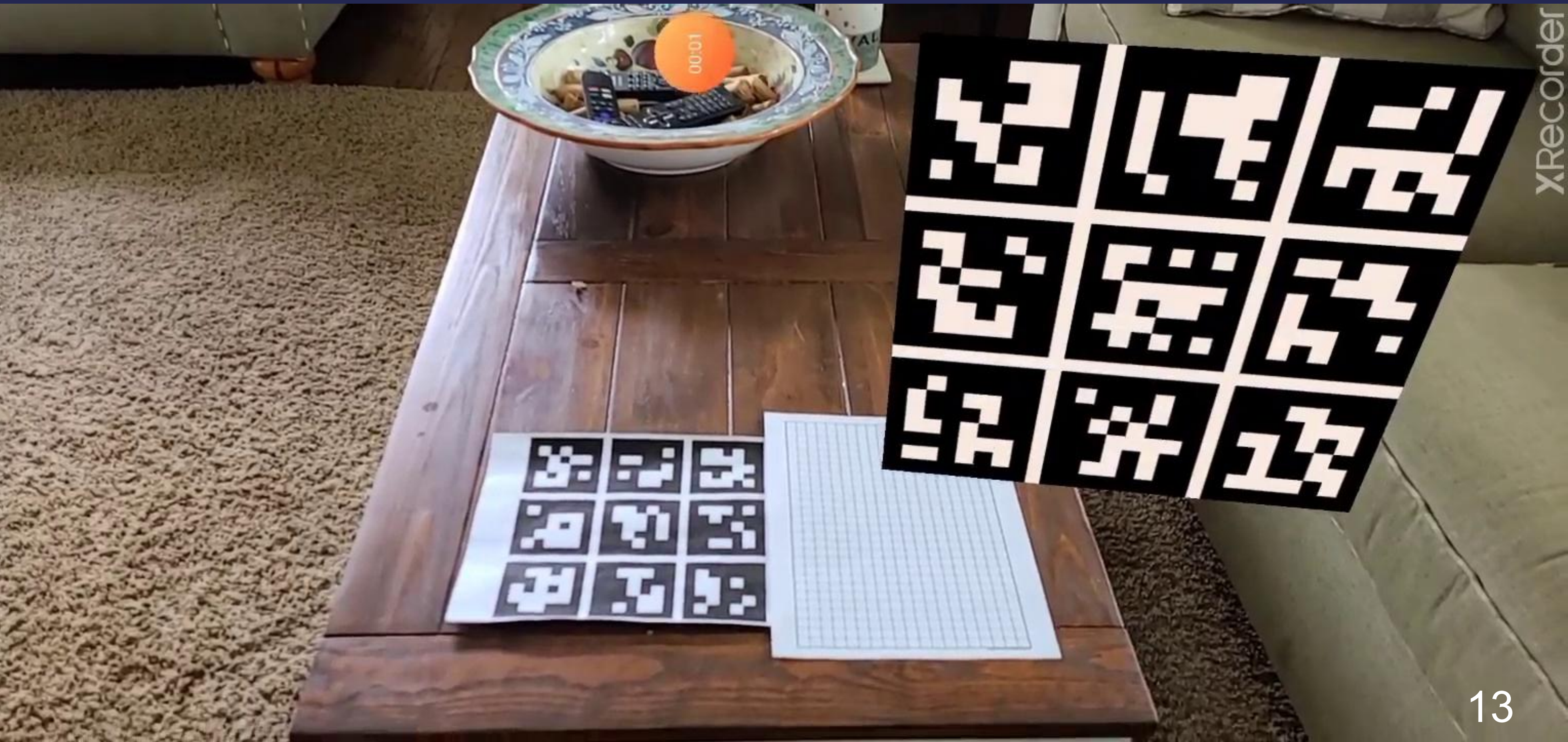
Spatial Inconsistency



Viewing the same static object from two times or at the same time from two different devices

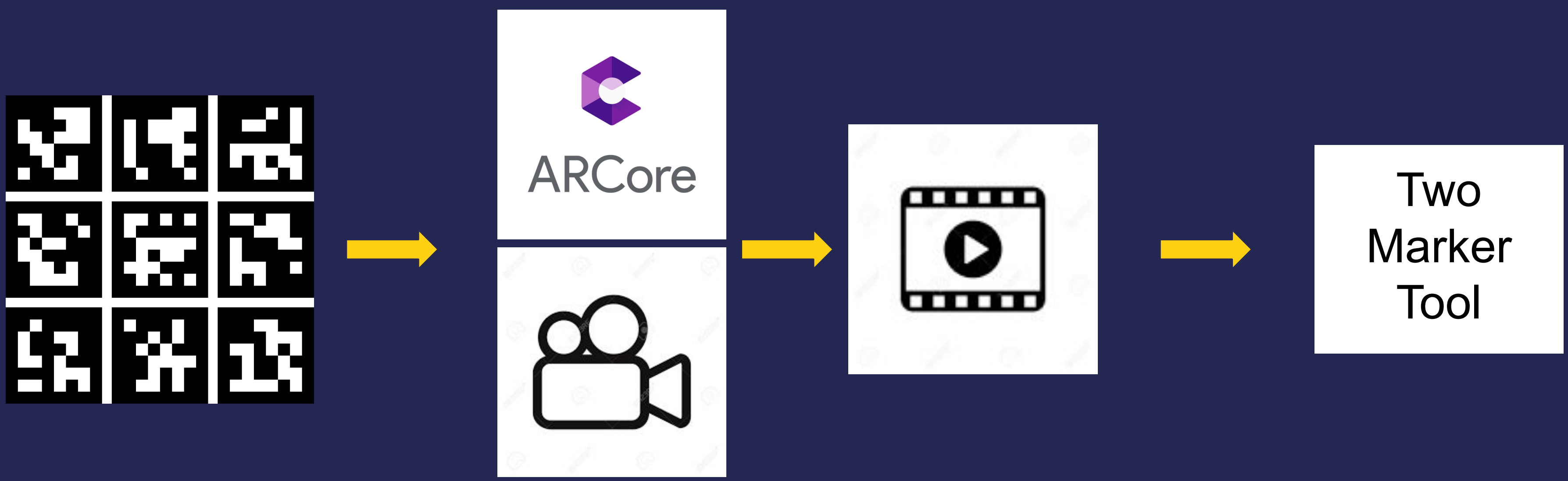
Two Marker Method Idea

Why not make the virtual object itself a marker board?



Two Marker Method Idea

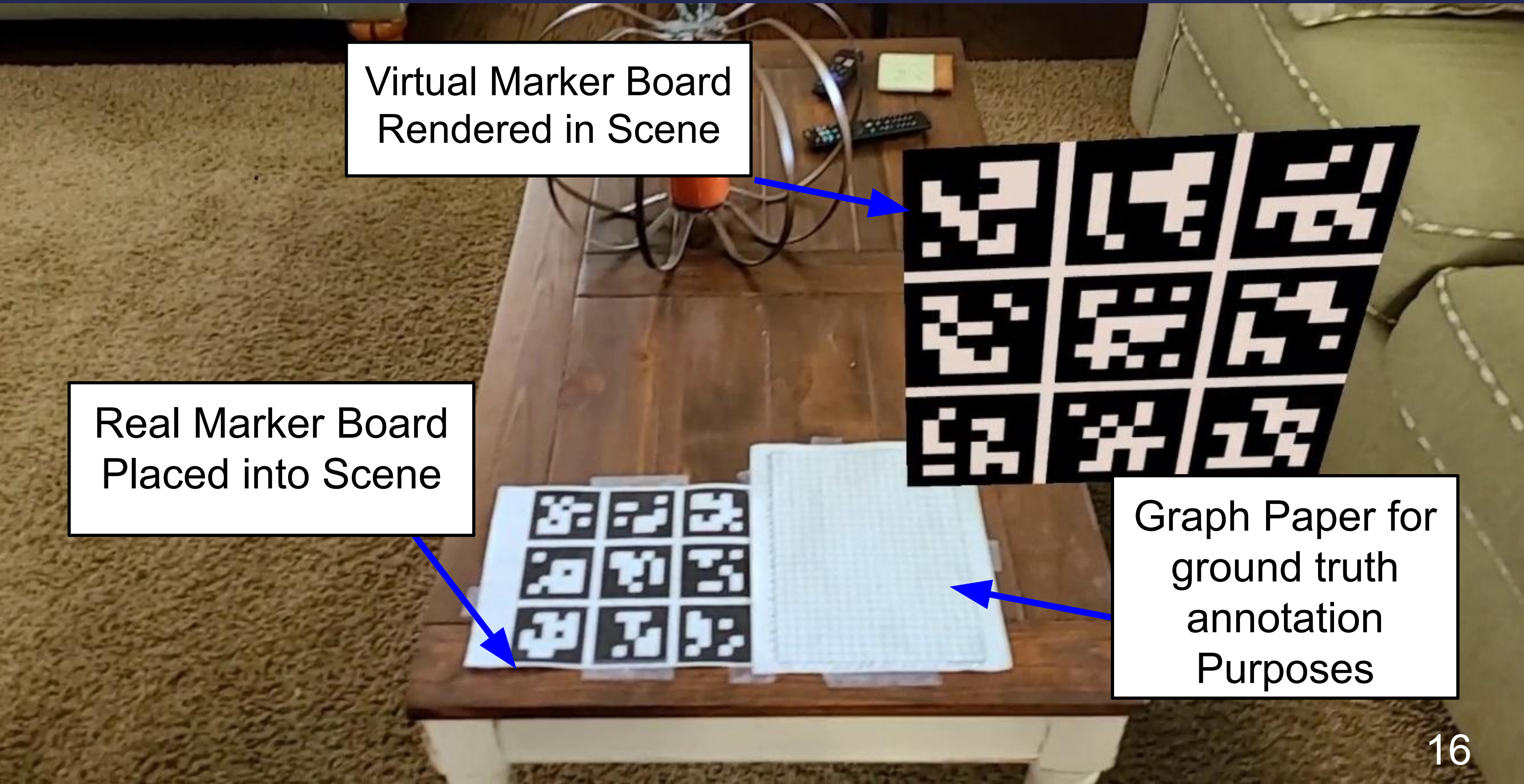
1. Place a real ArUco marker board in the scene
2. Run desired AR-framework
3. Record video including the real and virtual marker boards
4. Run PnP and compare measurements



Experiment Setup:

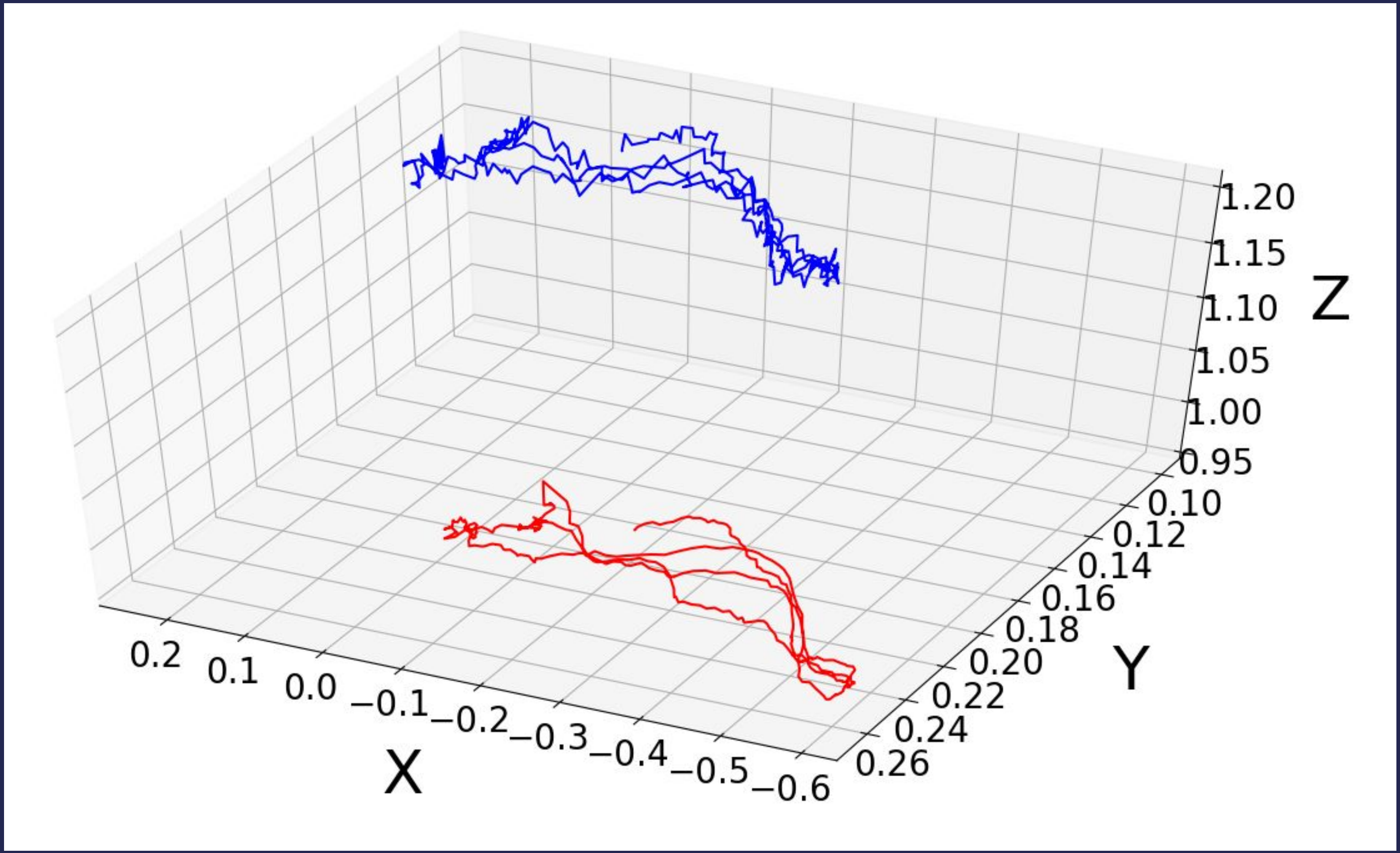
- Tested on Samsung Galaxy s7 and Galaxy S20
- Tested on knee-high tables.
- Tested both indoors in house and backyard (Campus Shutdown)
  - Using ARCore
- Multiple movement strategies:
  - Side to side (markers visible)
  - Full rotation (one marker only visible half the time)
  - Leave and return (markers visible at beginning and end with walking)
- 15 videos between 30-60 seconds at 30fps
- 3 videos approximately 2:30 at 30fps
- 268 hand-annotated frames

Experiment Setup for RealityCheck



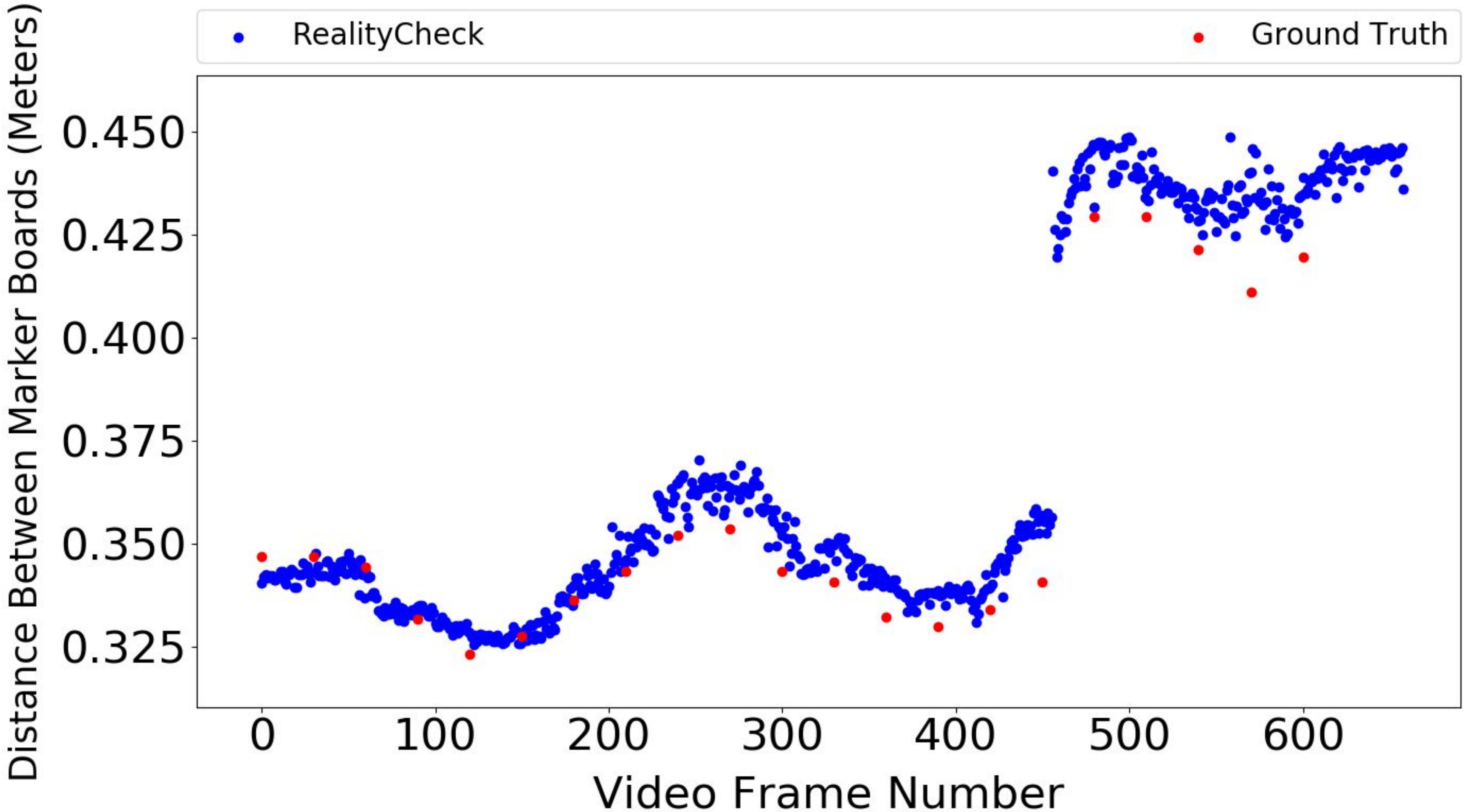
Example Result:

- Blue virtual marker estimate vs red real marker
- RealityCheck is able to track both markers.

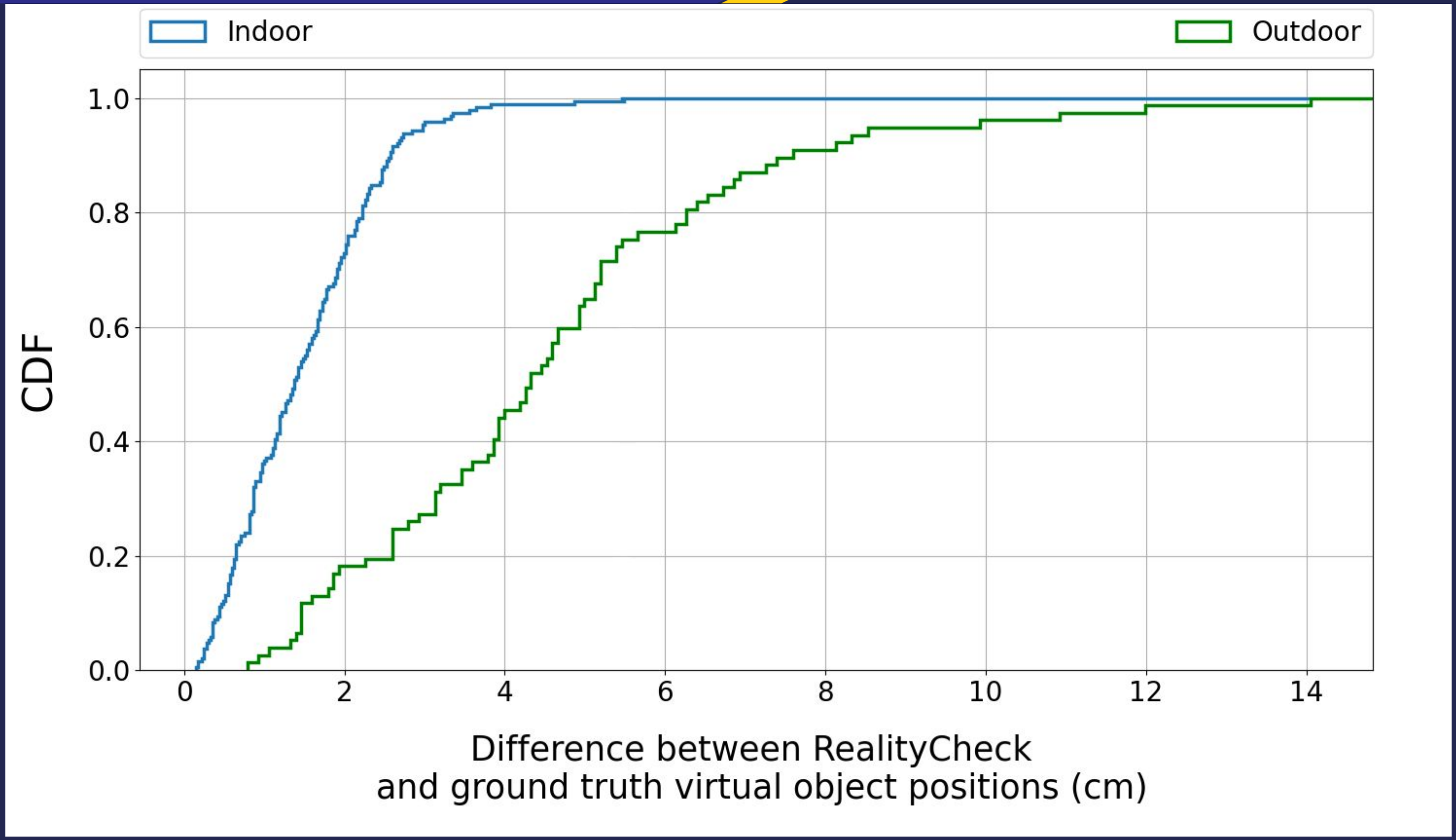


Example Result:

- RealityCheck successfully catches large jumps



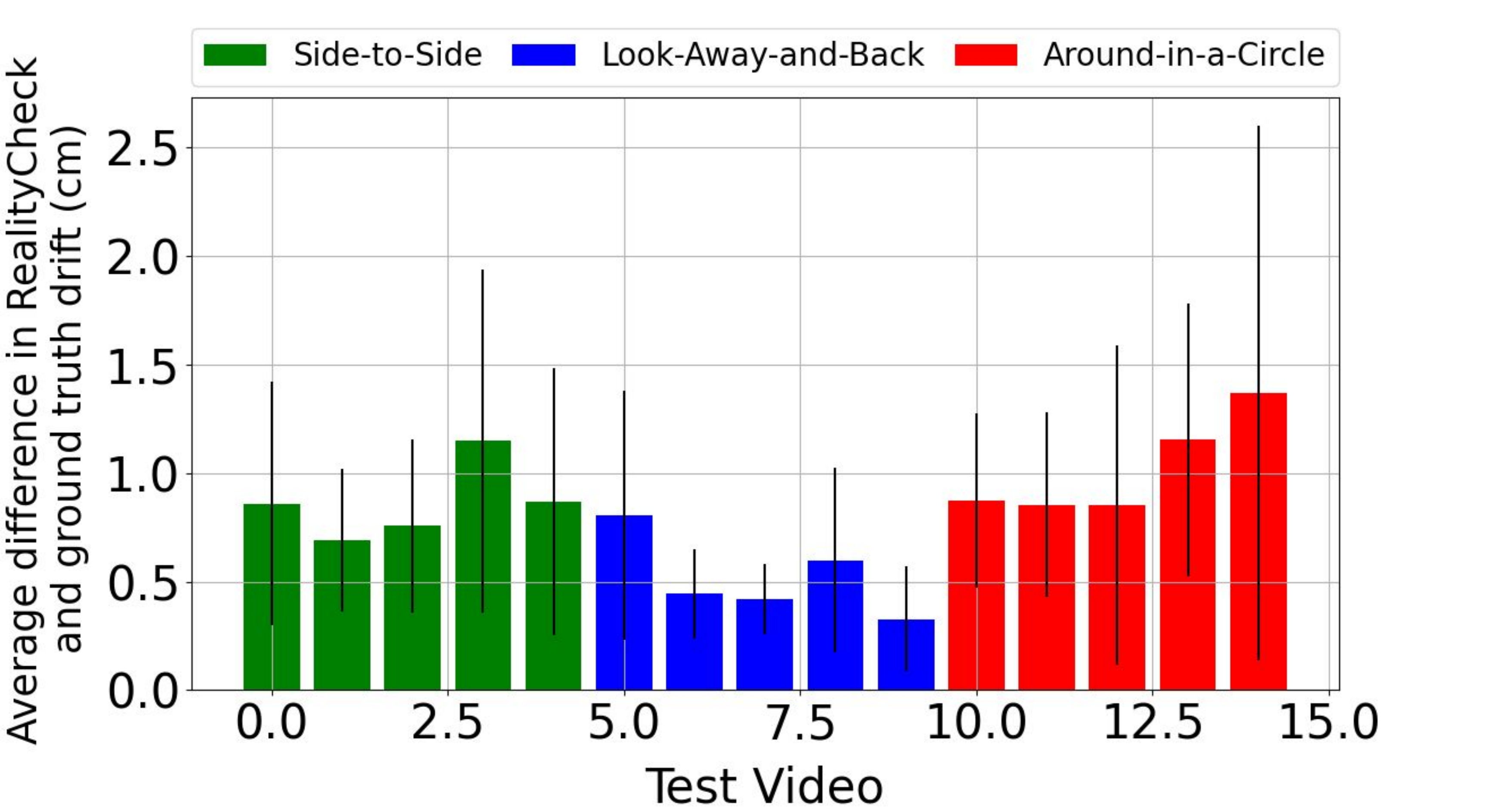
Main Results:



- Median indoor error of 1.36cm
- Over 90% of frames have less than 2.5cm error
- Poor lighting outdoors with moving objects

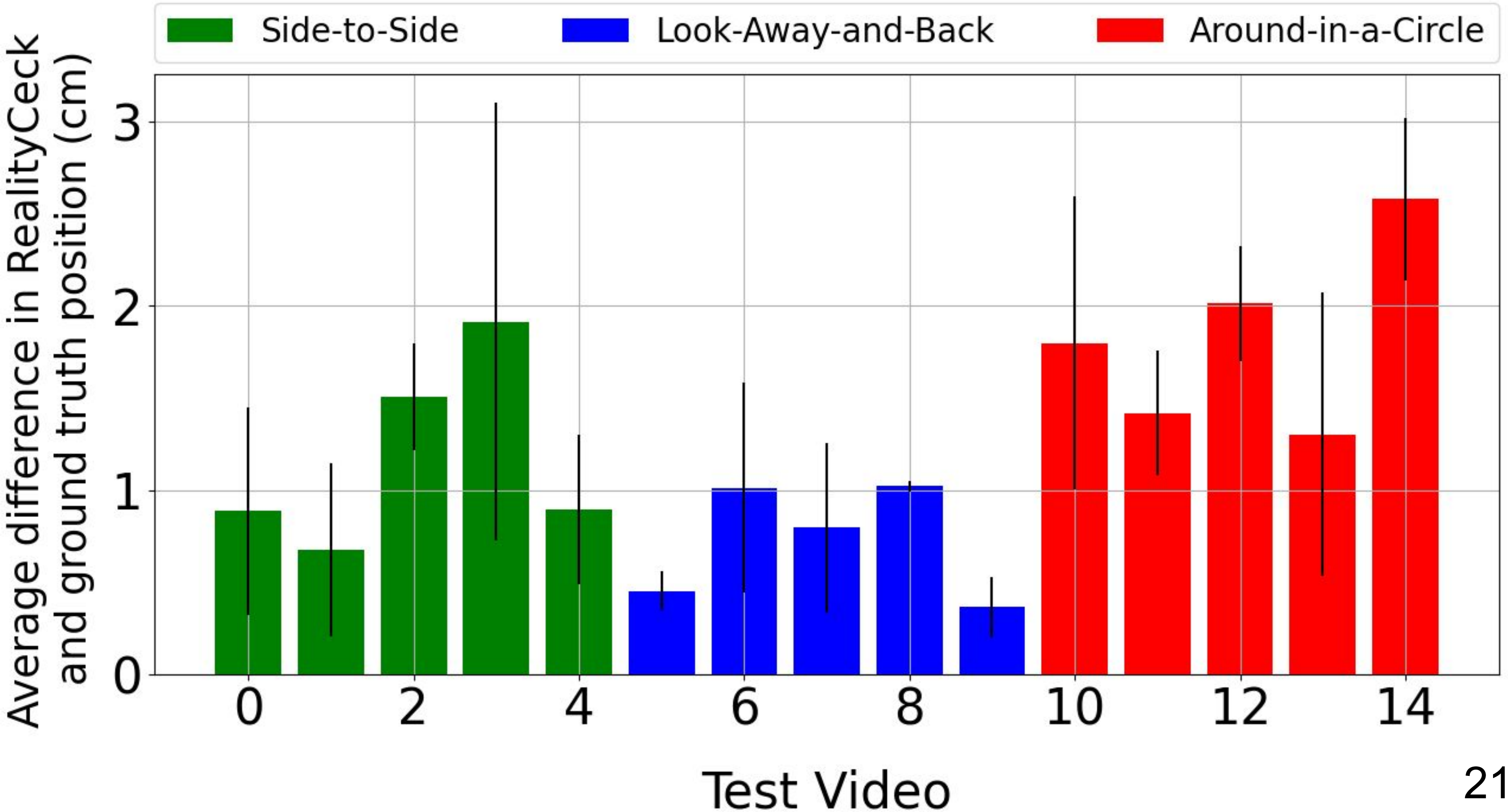
Effects Under Movements

- Most accurate when markers are viewed at non-extreme angles



Multi-User Experiment

- Randomizing image pairs to simulate virtual object spatial inconsistency across different users



Conclusions

- Spatial inconsistency of virtual objects over time/space is a problem in mobile augmented reality
- We propose a method using real and virtual fiducial markers to measure the spatial inconsistency
- Our evaluation, using Google ARCore, shows an accuracy of 1.5 cm on average in indoor scenarios
- RealityCheck open source at: https://sites.google.com/view/arrealitycheck/home

Thank you!
Questions?

Thanks

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