

Mixed Reality Trompe L'oeil for Fun and Profit

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Perception and Interaction

Microsoft Research AI

Trompe l'oeil: “Deceive the eye”

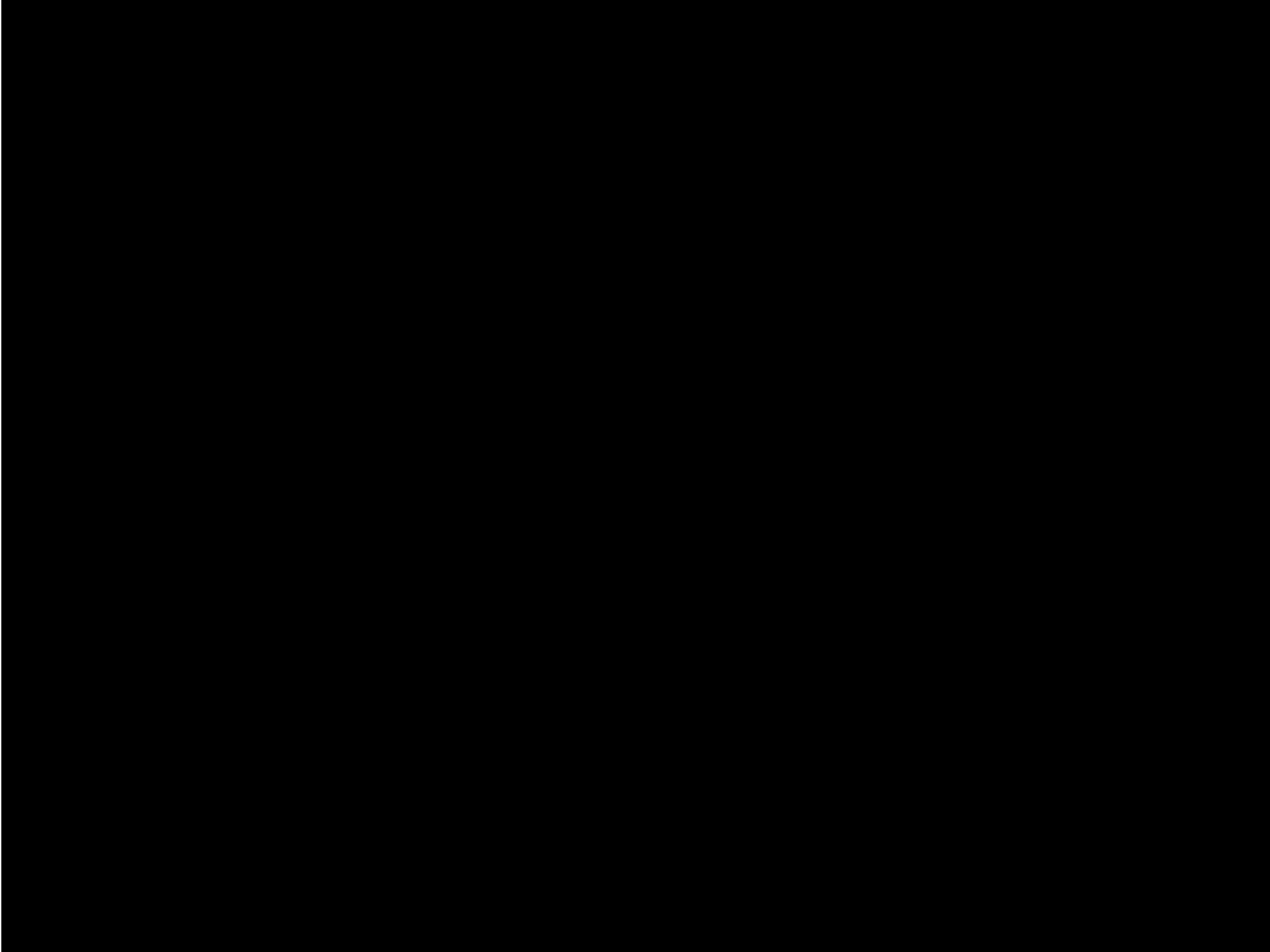
an art technique that uses realistic imagery to create the optical illusion that the depicted objects exist in three dimensions



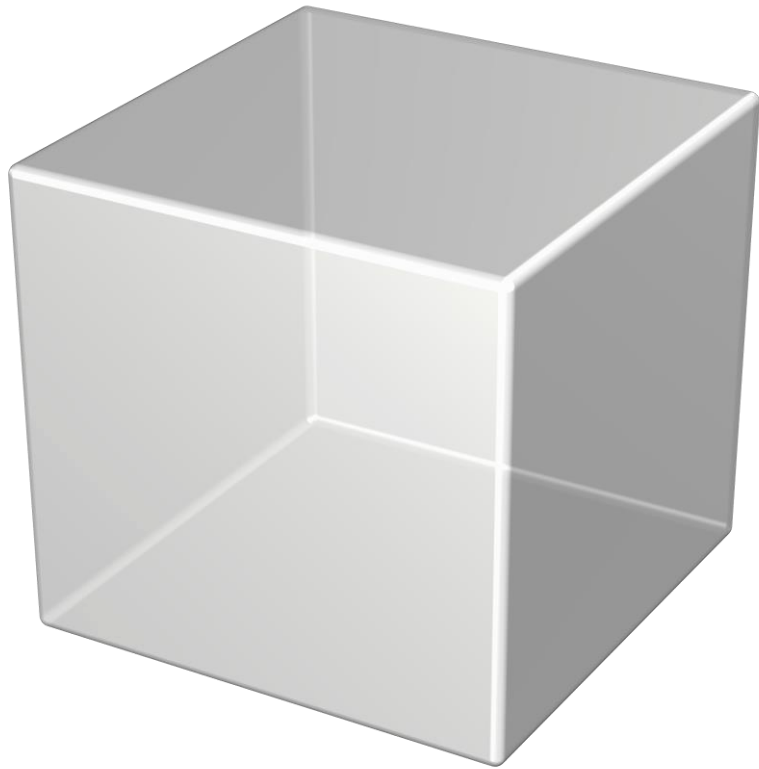
Realistic haptics in VR is not easy



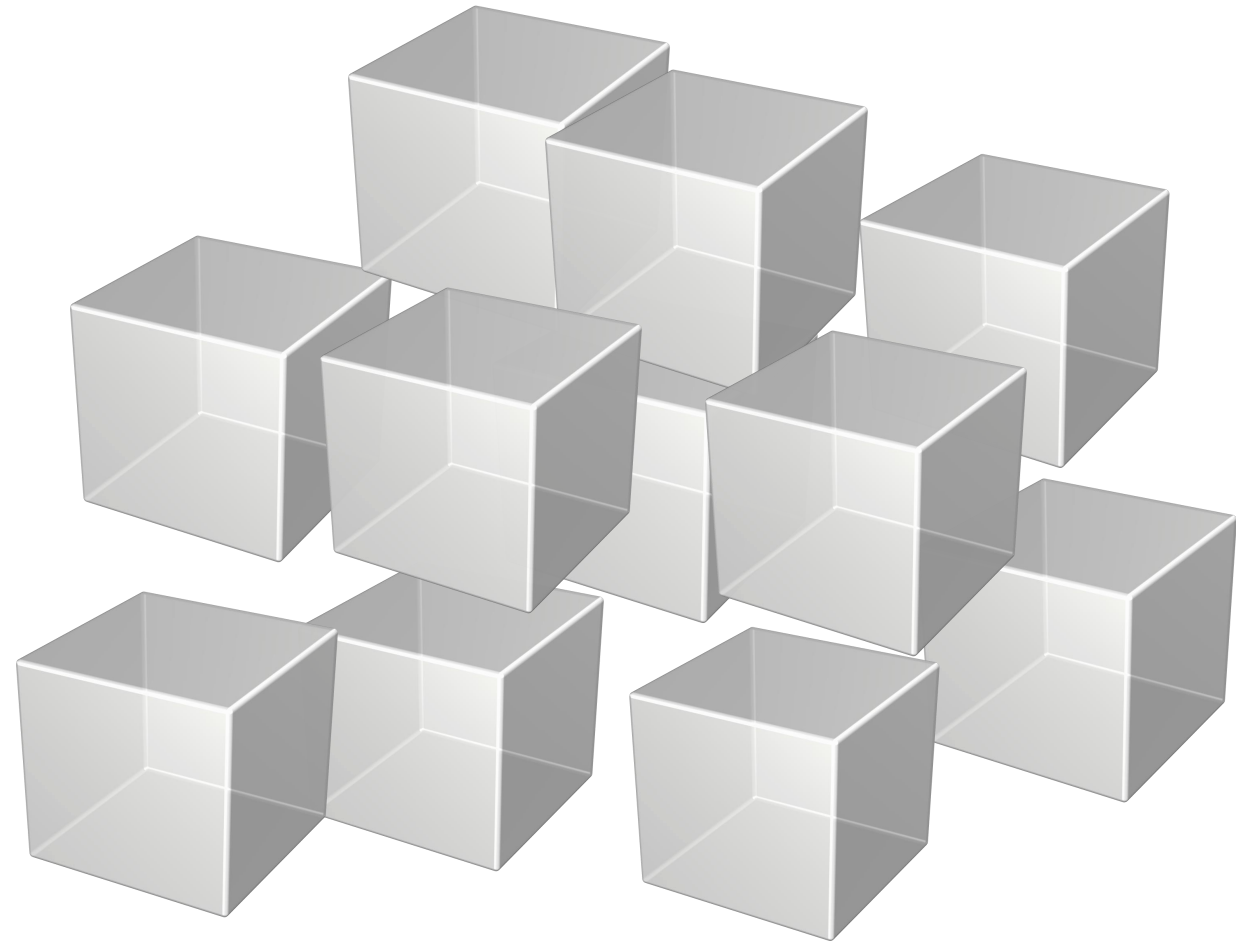
CyberGrasp Glove – Image by Leonardo Crescenti



Passive Haptics in VR



Passive Haptics in VR – Does not Scale



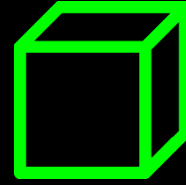
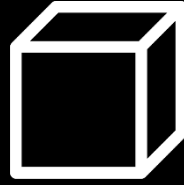
Kinect V2 + Oculus DK2 HMD





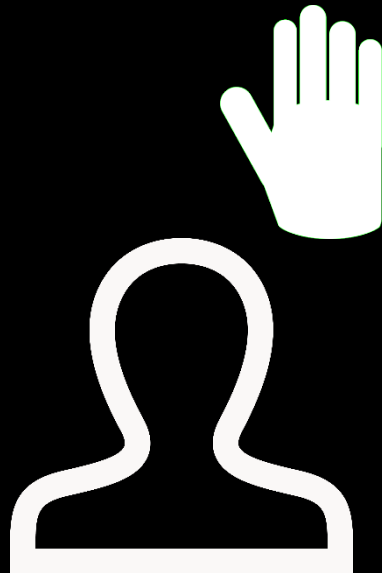


physical
cube



virtual
cube

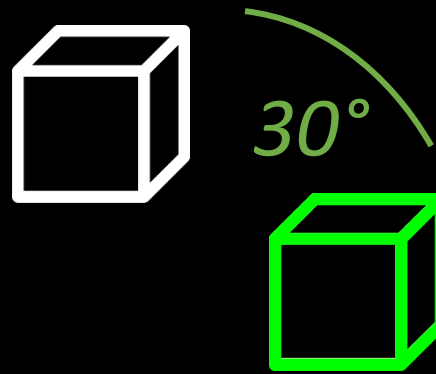
*The Rendered Body
Shifts to The Right*





Body Warping

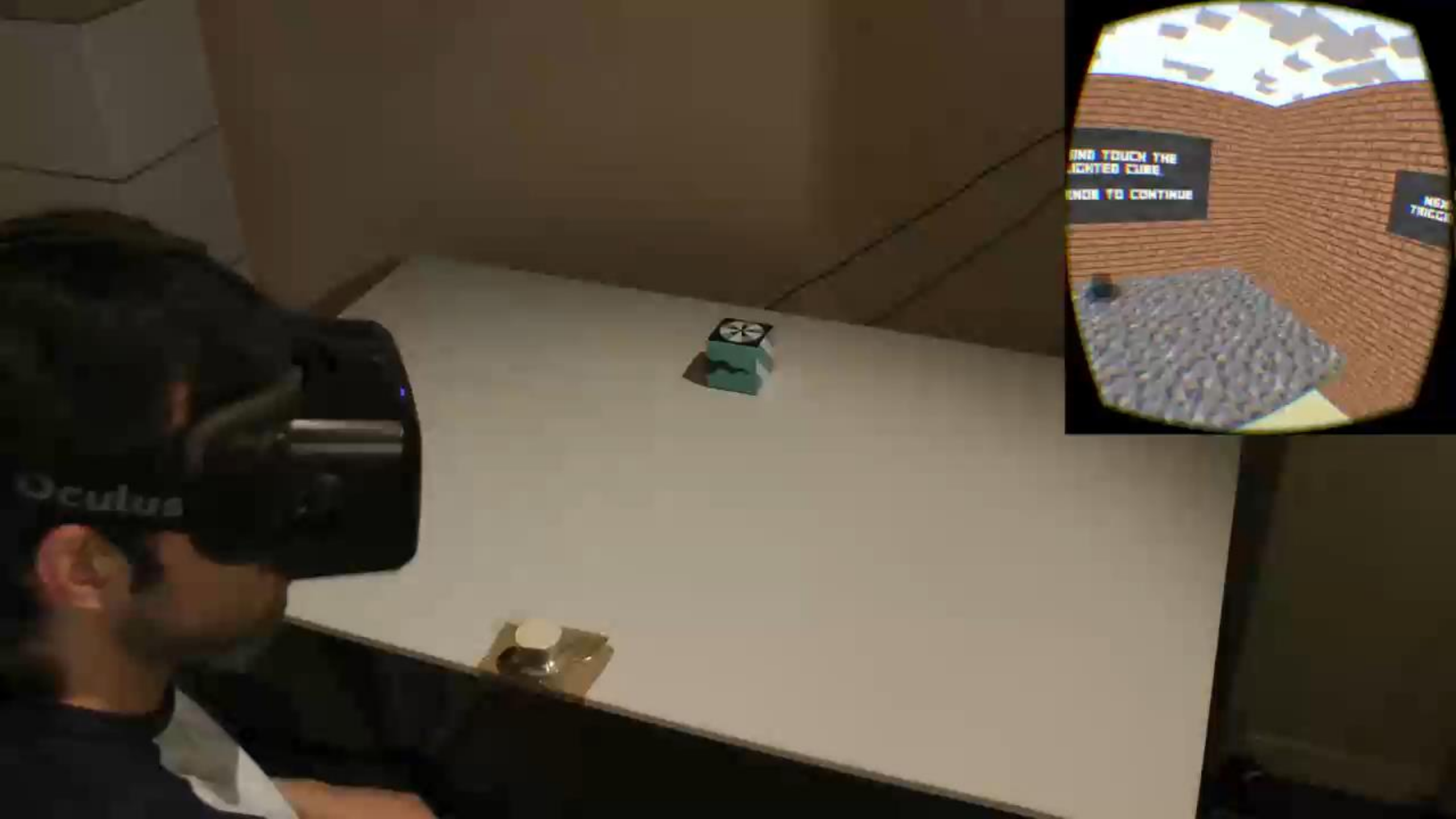
physical
cube



virtual
cube

*The World Also Rotates
(At Different Rate)*







Hybrid Warping



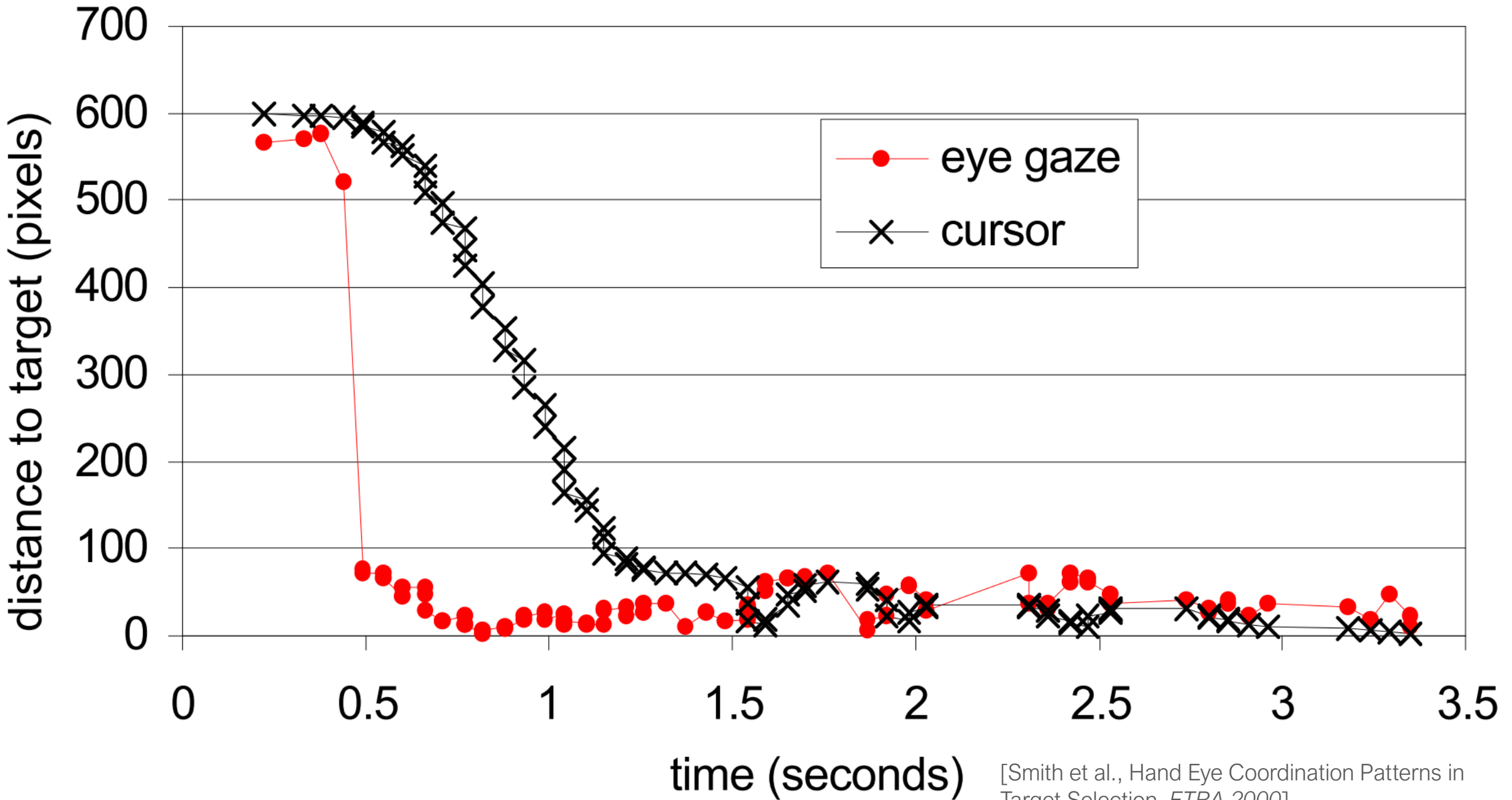
Limitations

- Need to know which object you are reaching for (we tell you)
- Need to press the button before reaching
- No accounting for mismatch in scale and shape

SMI eye-tracking module

250 hz eye-tracker
on Oculus DK2





[Smith et al., Hand Eye Coordination Patterns in Target Selection, *ETRA 2000*]

predicted target

actual target

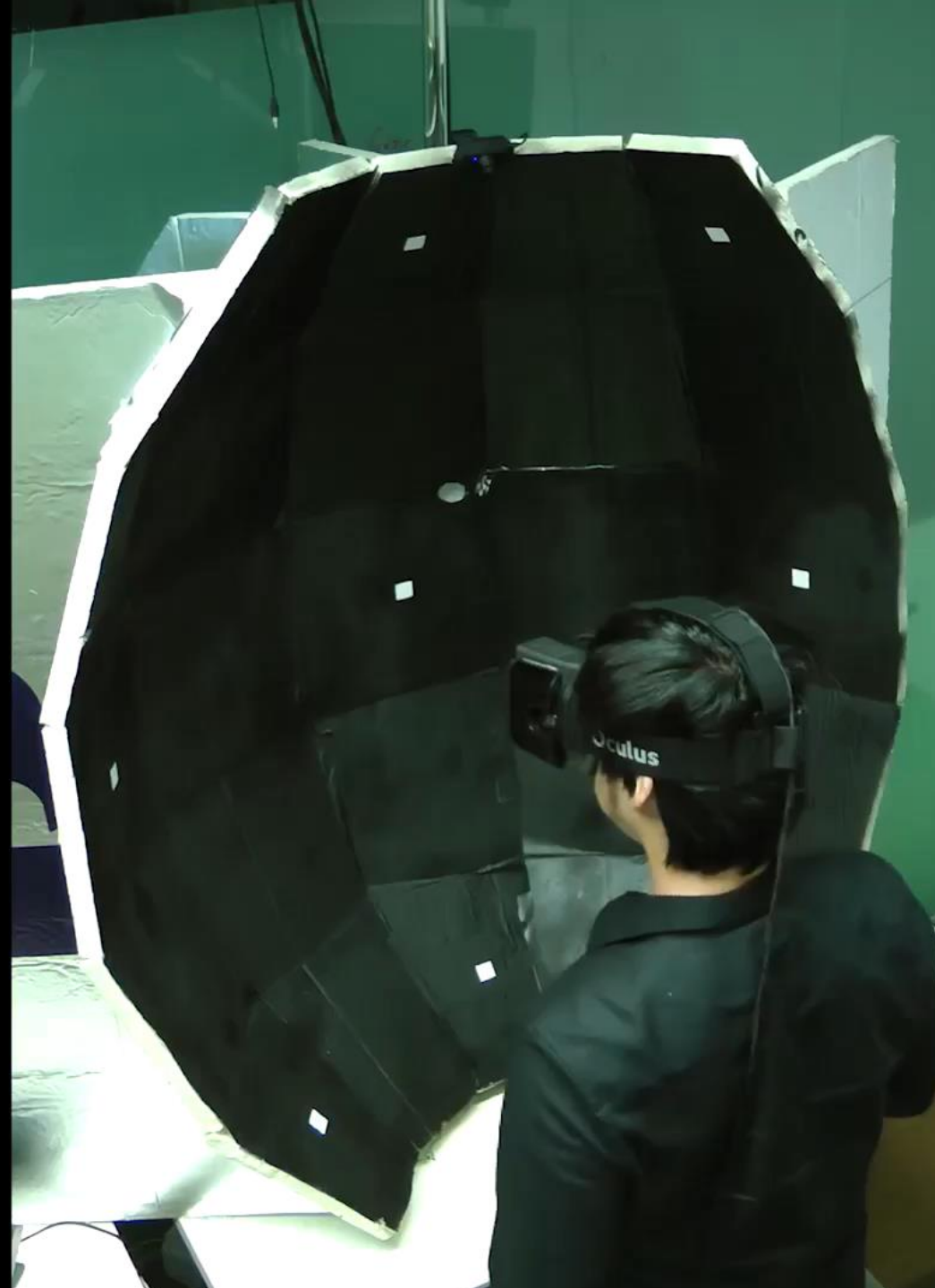
| | p0 | p1 | p2 | p3 | p4 | p5 | p6 | p7 | p8 | p9 | p10 | p11 | p12 | p13 | p14 | p15 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| a0 | 106 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| a1 | 0 | 108 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| a2 | 0 | 1 | 107 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| a3 | 0 | 0 | 0 | 108 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| a4 | 0 | 0 | 0 | 0 | 108 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| a5 | 0 | 0 | 0 | 0 | 0 | 107 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| a6 | 0 | 0 | 0 | 0 | 0 | 0 | 107 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| a7 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 106 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| a8 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 104 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| a9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 107 | 0 | 0 | 0 | 0 | 0 | 1 |
| a10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 108 | 0 | 0 | 0 | 0 | 0 |
| a11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 106 | 0 | 1 | 0 | 0 |
| a12 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 5 | 3 | 0 | 0 | 95 | 1 | 1 | 1 |
| a13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 104 | 0 | 0 |
| a14 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 104 | 0 |
| a15 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 2 | 100 |

12 participants (7 female), ages 24-30 (M=27.6)

prediction accuracy: 97.5%, 2.04 seconds before touching

Sparse Haptic Proxy

Touch Feedback in Virtual Environments
Using a General Passive Prop



Projected Augmented Reality: Holograms without Headsets









Perspective Rendering

RoomAlive Toolkit

- Interactive projection mapping
- Support for multiple Kinects + multiple projectors
- Robust calibration tool
- Projection mapping sample
- MIT license
- <http://github.com/Kinect/RoomAliveToolkit>

Projection Mapping

- What to render on the projector so that viewer has a desired perception?
 - Must account for irregularity of projection surface, pose of projector, viewer's eye position



Edgar Mueller



Felice Varini



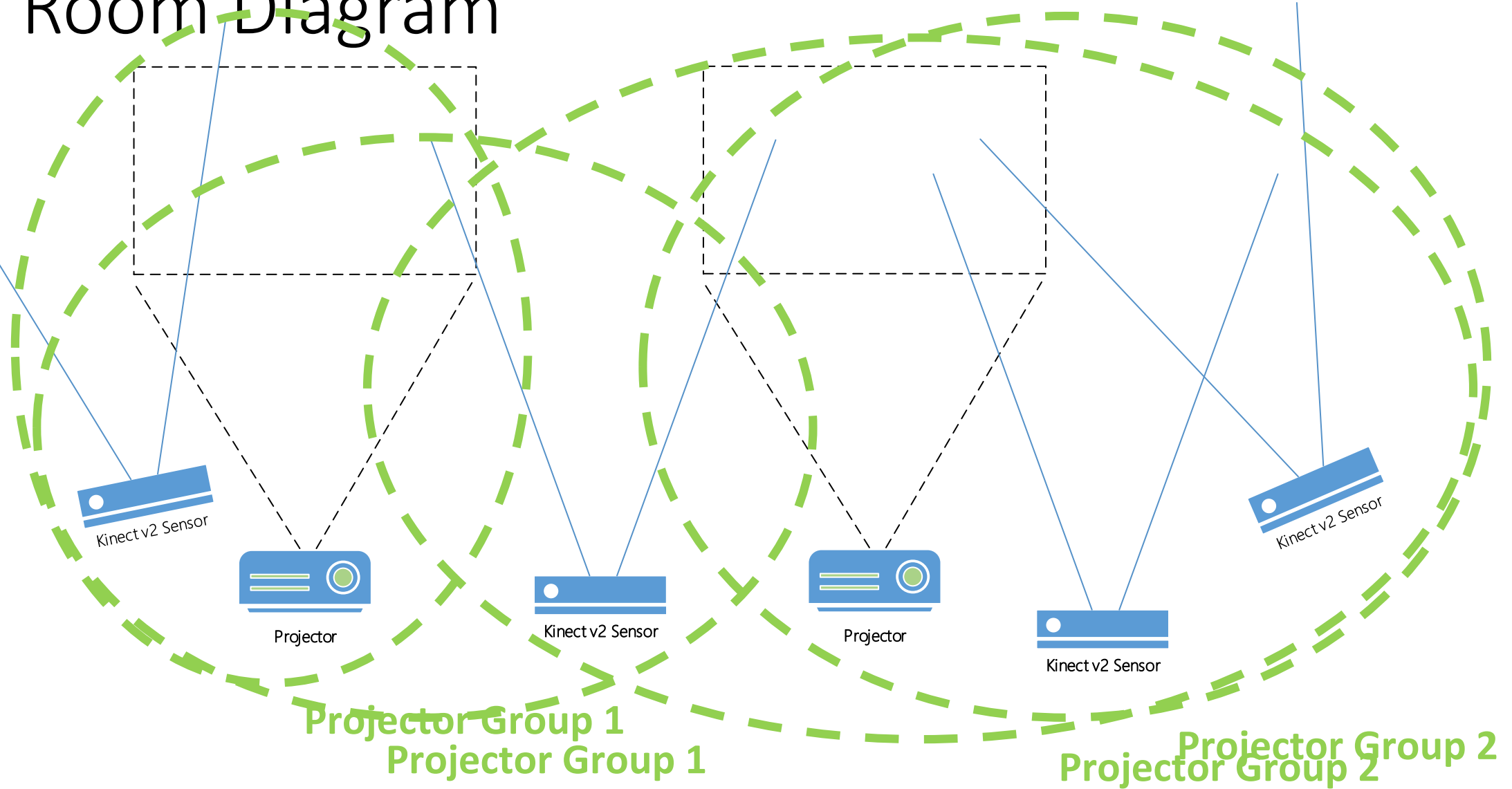
Calibration

- Finds the position and pose of *every* Kinect and projector along with focal length and lens distortion
- Projectors display Gray codes which are observed by all Kinect color cameras

Calibrating 3 Kinects and 3 projectors



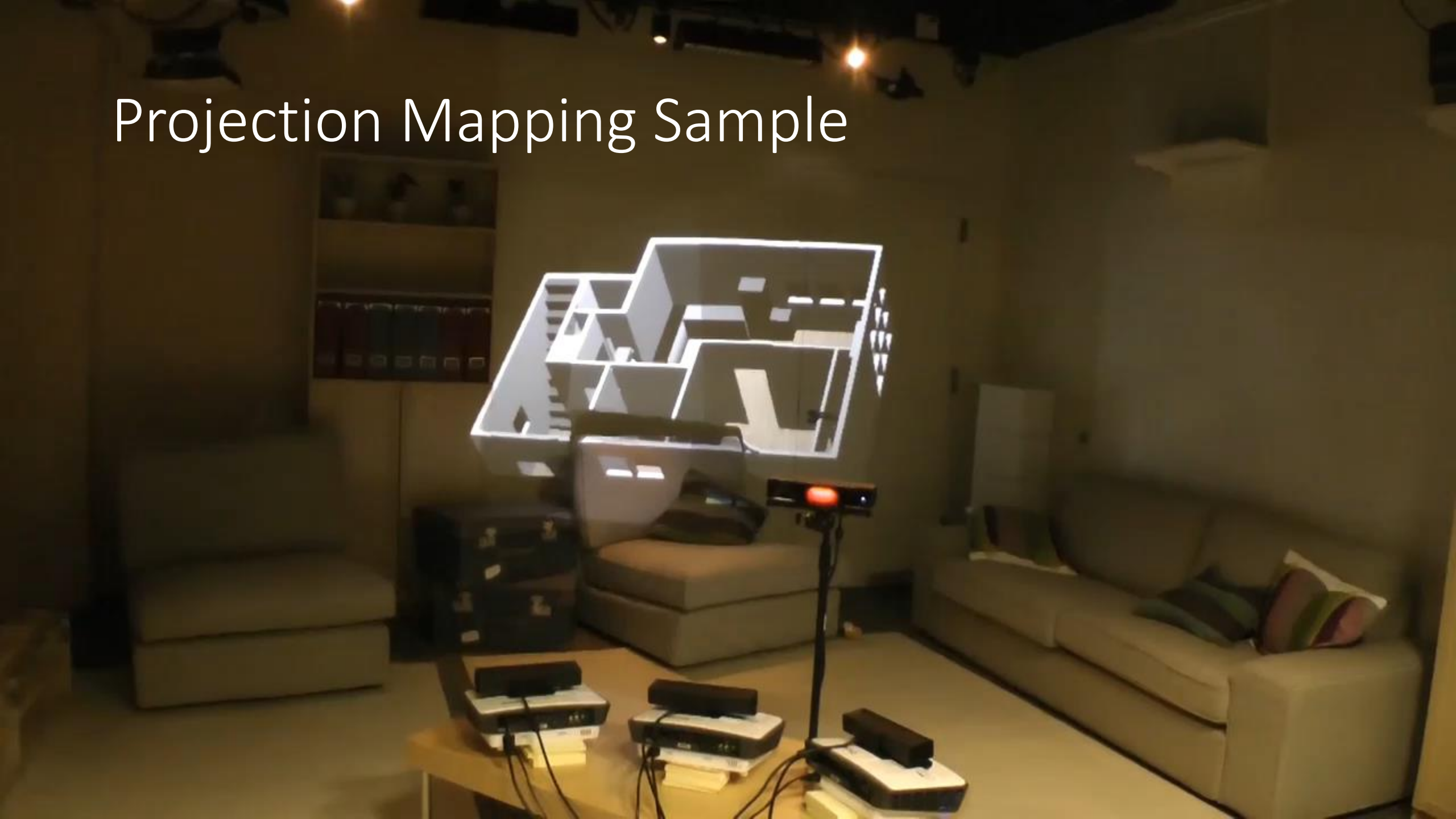
Room Diagram

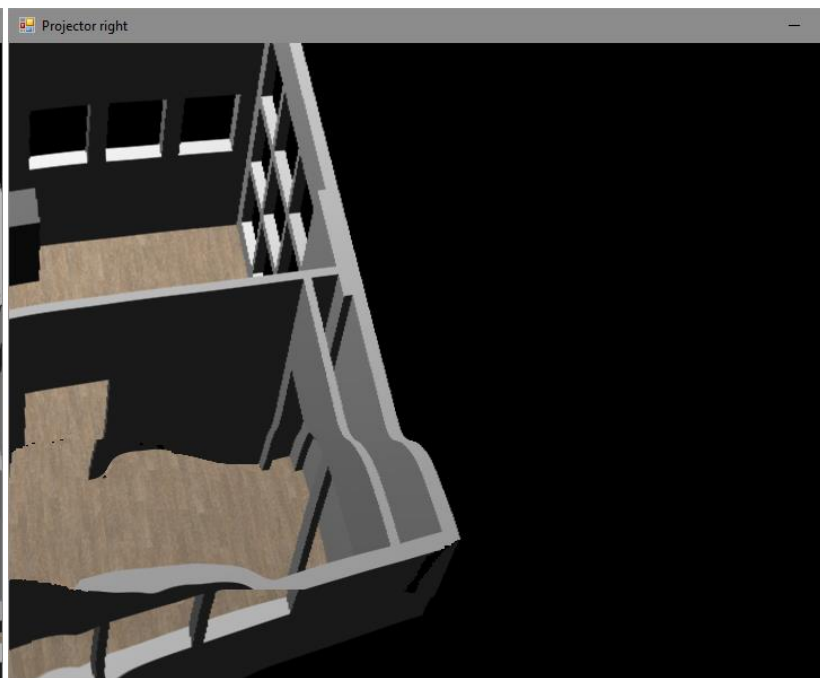
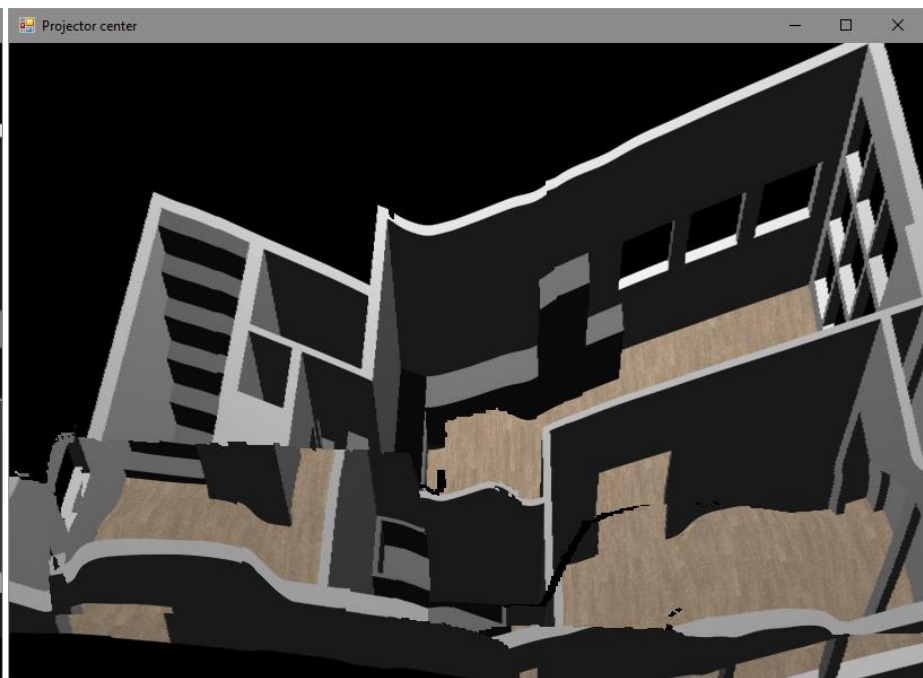
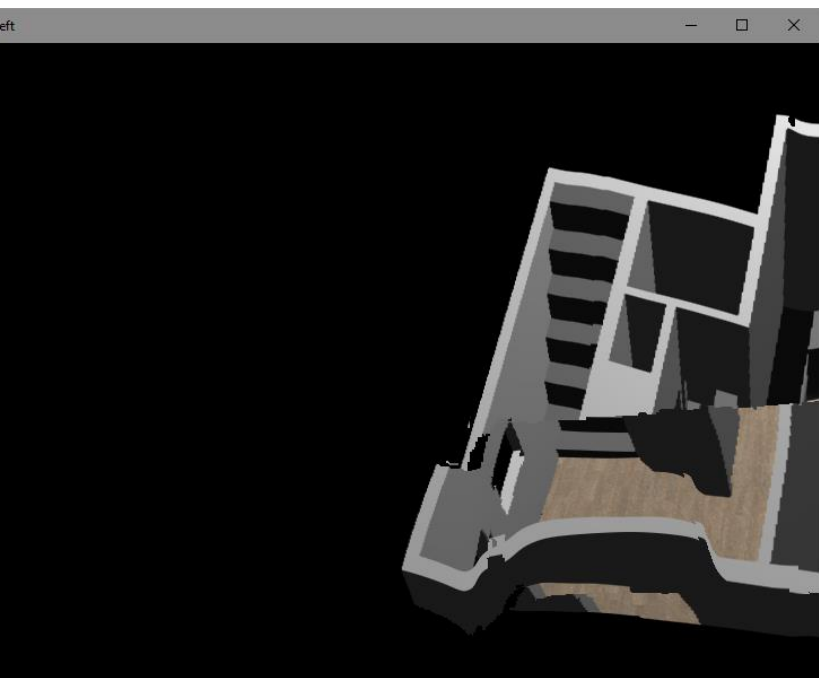
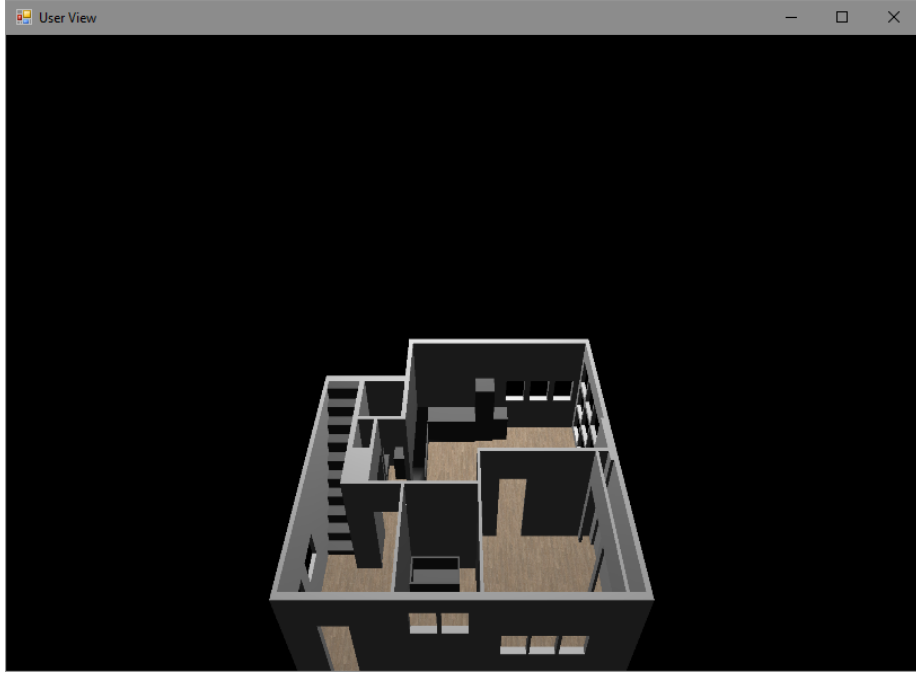


Projection Mapping (briefly)

- A 'user view' off-screen render is performed.
- A graphics projection matrix is assembled for each projector in the ensemble.
- The projector's projection matrix is combined with calibrated projector and depth camera pose information
 - Create a transformation matrix mapping a 3D point in the coordinate frame of a given depth camera to a 3D point in the projector's view volume.

Projection Mapping Sample





graphics: 60.2Hz
network: 892.5Mbps
depth (Hz):
color (Hz):

| | | | | | | | |
|------|------|------|------|------|------|------|------|
| 27.8 | 28.6 | 30.0 | 26.7 | 27.0 | 28.1 | 27.1 | 26.3 |
| 22.7 | 24.8 | 22.7 | 22.6 | 22.5 | 17.8 | 19.1 | 18.8 |



Task Manager

File Options View

Processes Performance App history Startup Users Details Services

CPU 54% 3.68 GHz

Memory 6.3/31.9 GB (20%)

Disk 0 (D:) 0%

Disk 1 (C:) 4%

Disk 2 (E:) 2%

Ethernet S: 11.0 R: 962 Mbps

Wi-Fi Not connected

Bluetooth Not connected

Fewer details | Open Resource Monitor

Ethernet

Intel(R) 82579V Gigabit Network Conne...

Throughput 1 Gbps

60 seconds

Send 11.0 Mbps

Receive 962 Mbps

Adapter name: Ethernet

Domain name:

Connection type:

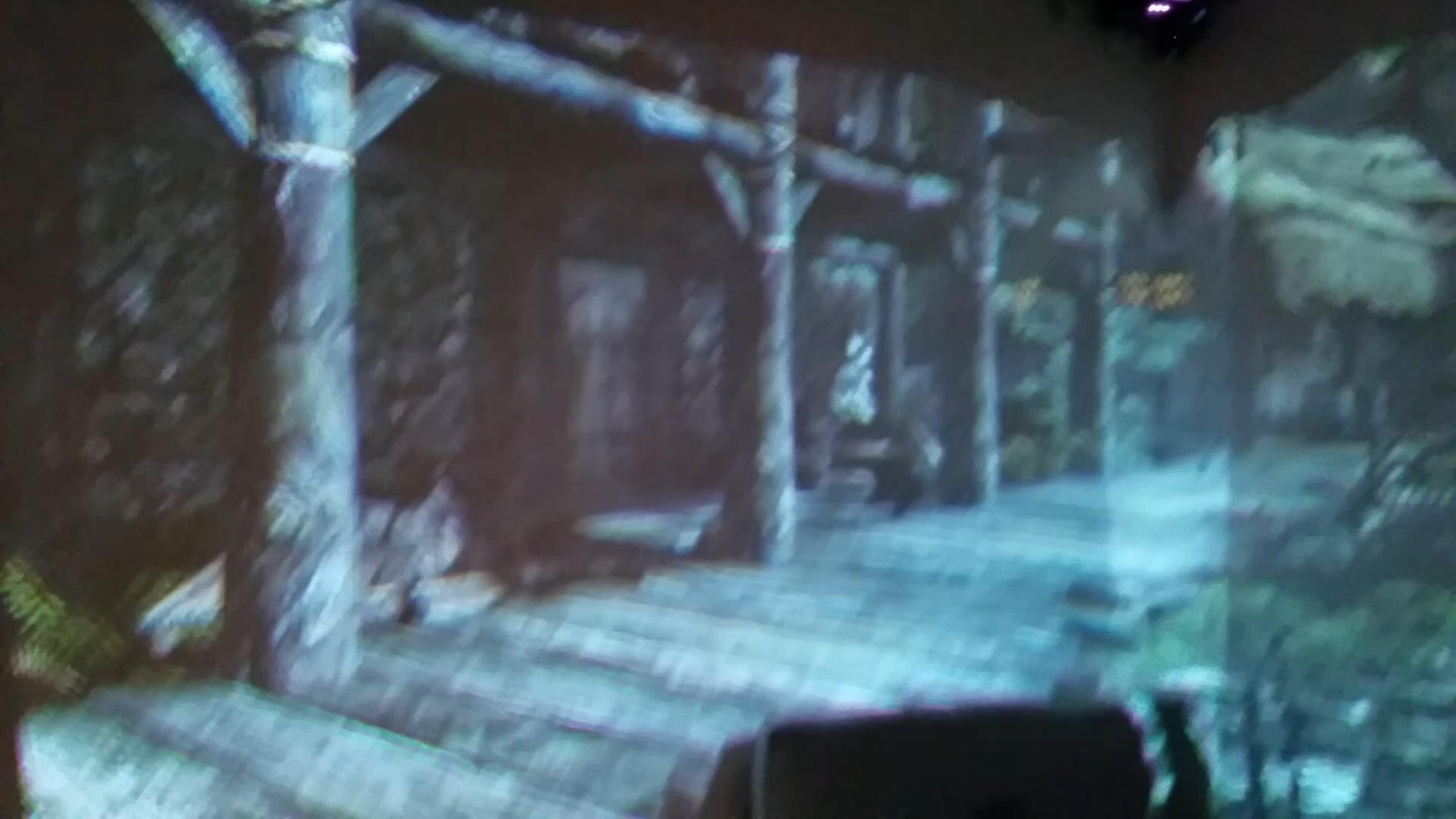
IPv4 address:

IPv6 address:

RealityCheck

Combining VR and projected AR





RealityShader (RoomAlive 2.0)

Rewritten from the ground up

Support for Kinect, RealSense, Azure Kinect

Refactored to support a variety of game engines (Unity, Unreal, etc)

OpenVR support