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ARIVE Lecture Series
XR: Virtual and Augmented Reality

# Volumetric Pixels

Holger Regenbrecht
University of Otago, Dunedin, New Zealand

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# Outline

1. Immersive Mixed Reality
2. Volumetric Video
3. Volumetric Tele-Copresence

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# Immersive Mixed Reality

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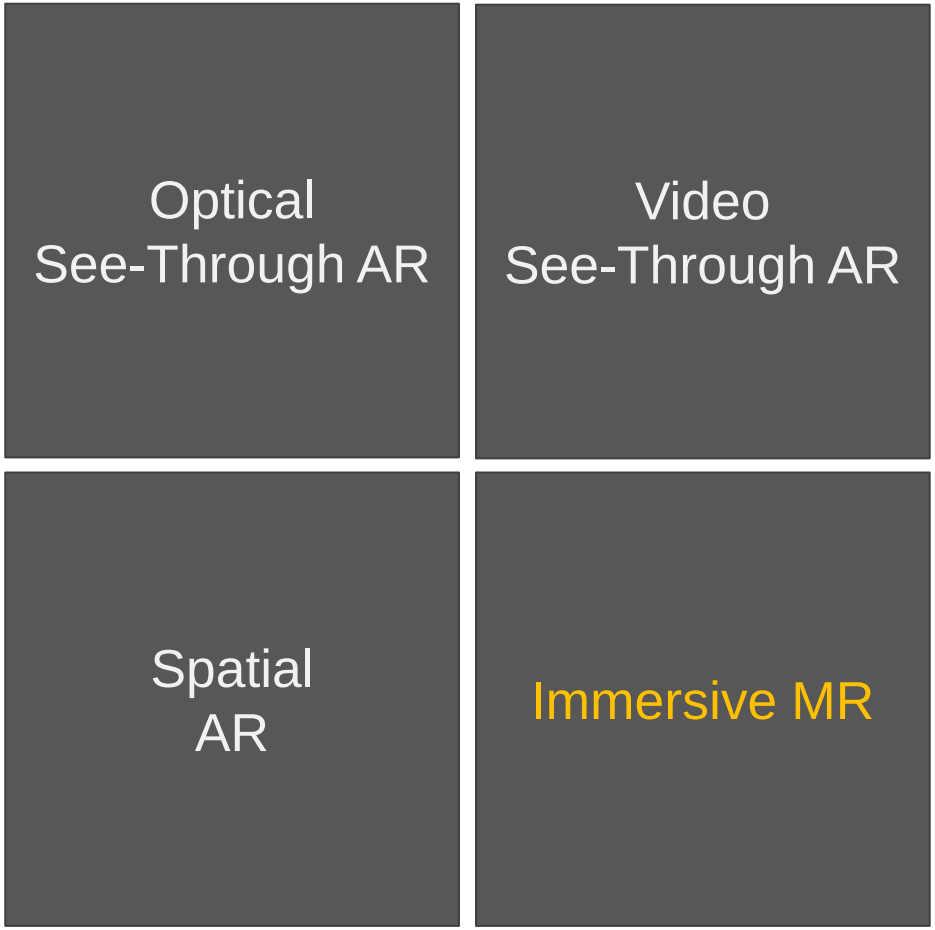
# Immersive Mixed Reality aka Remixed Reality

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# Immersive Mixed Reality aka Remixed Reality

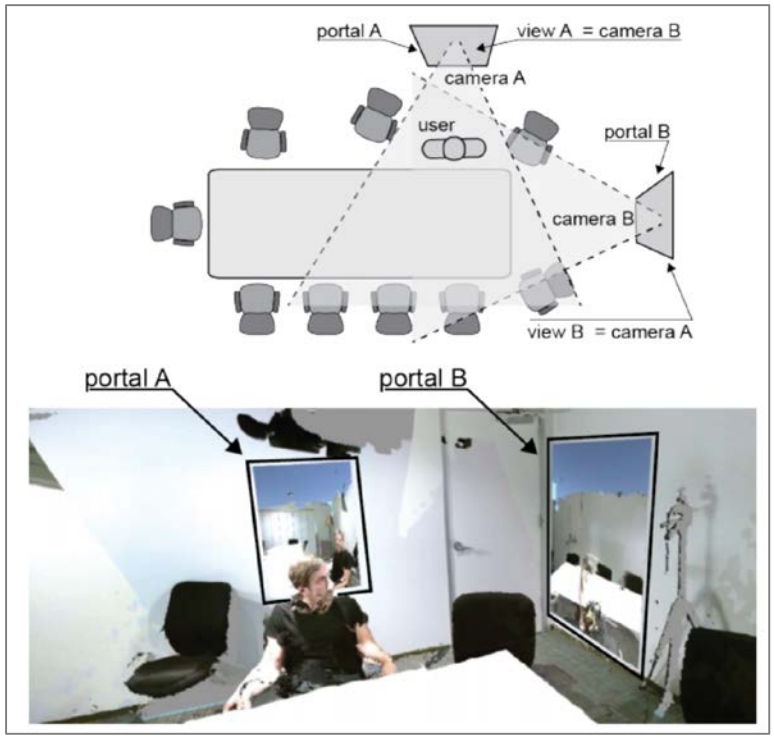
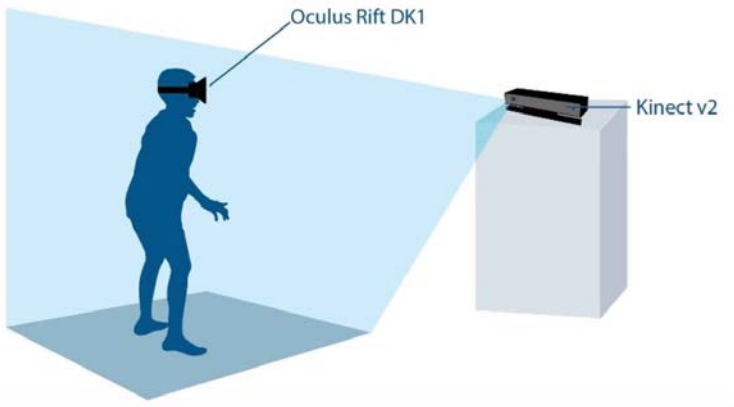



**Figure 10. The user has erased the table and chairs in the room and replaced them with virtual furniture (couch, table, chair). Note the virtual second floor with furniture on the top right. Users can teleport there to retrieve virtual objects.**

Lindlbauer, D., & Wilson, A. D. (2018, April). Remixed reality: manipulating space and time in augmented reality. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (pp. 1-13).

# Dassault Demo IEEE VR 2015




Dalai Felinto 2015
Dassault 2015

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# Dassault Demo IEEE VR 2015

Dalai Felinto 2015

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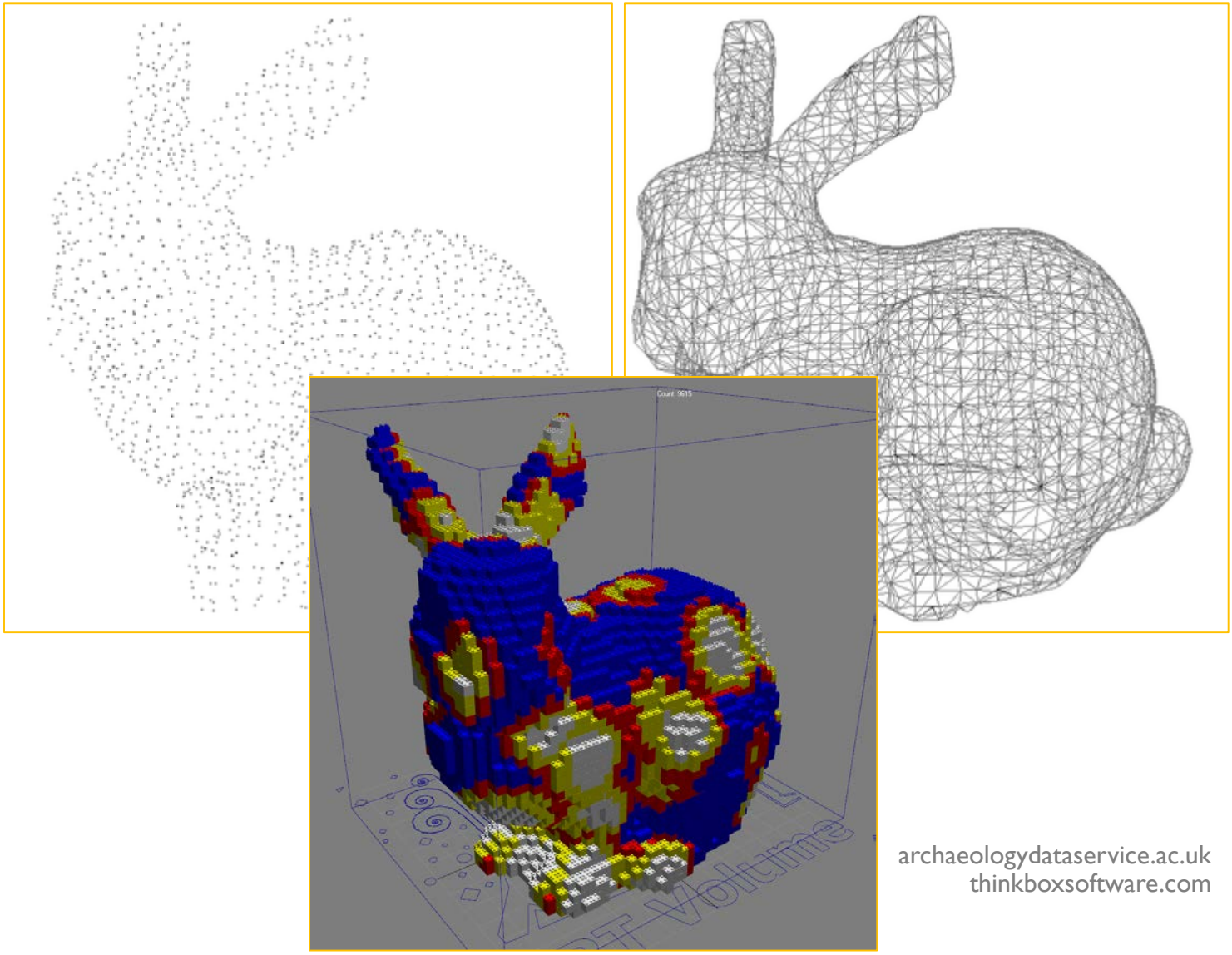
# Coherence



archaeologydataservice.ac.uk
thinkboxsoftware.com

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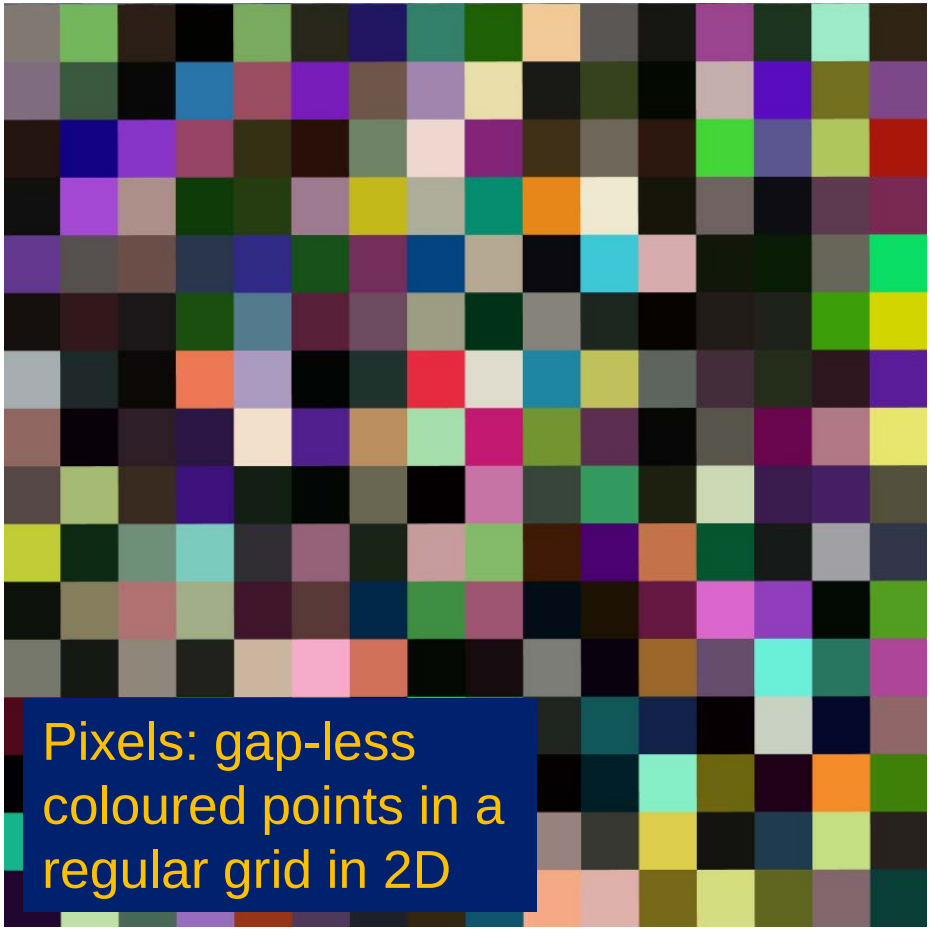
# From Pixels to Voxels



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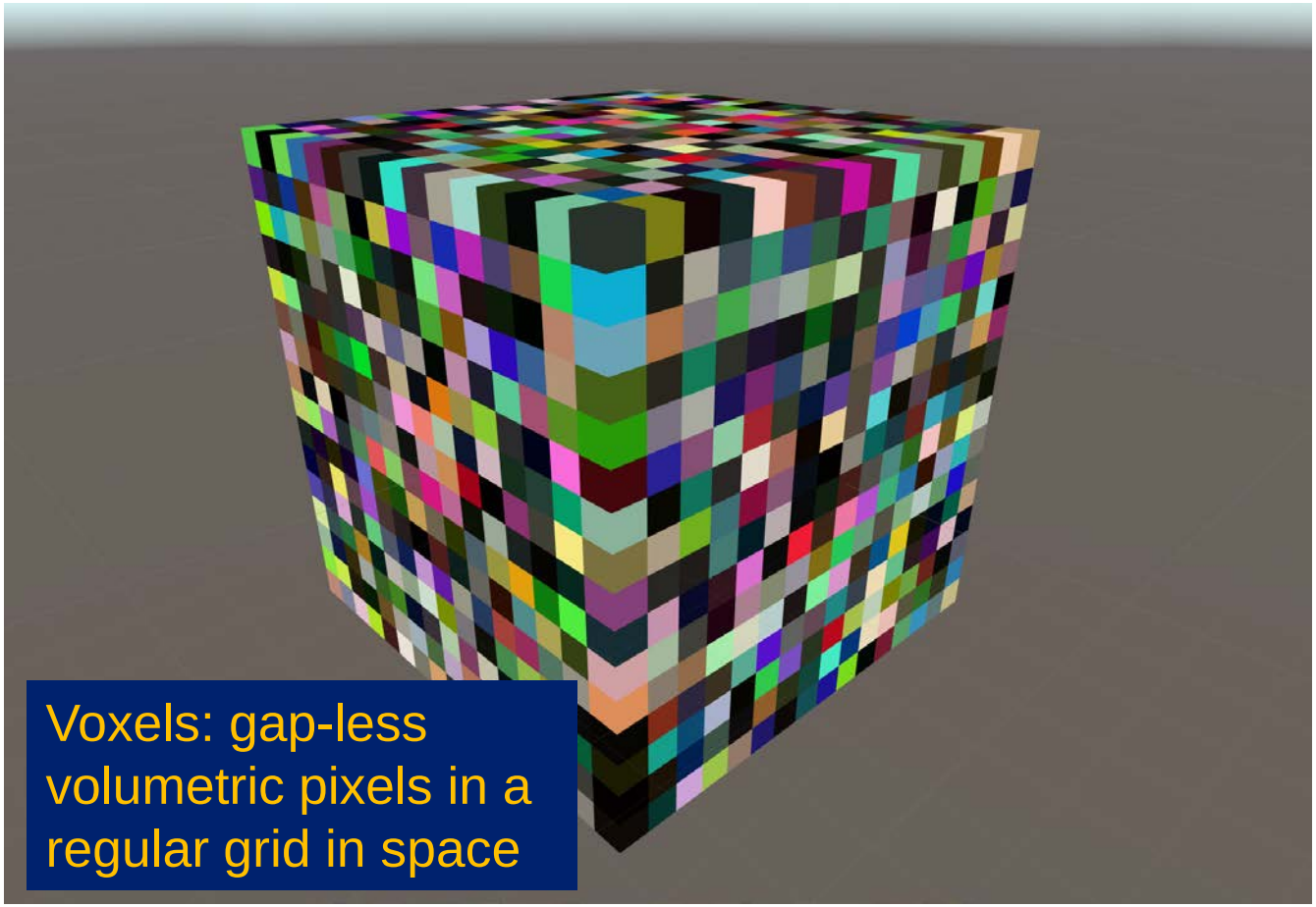
# From Pixels to Voxels



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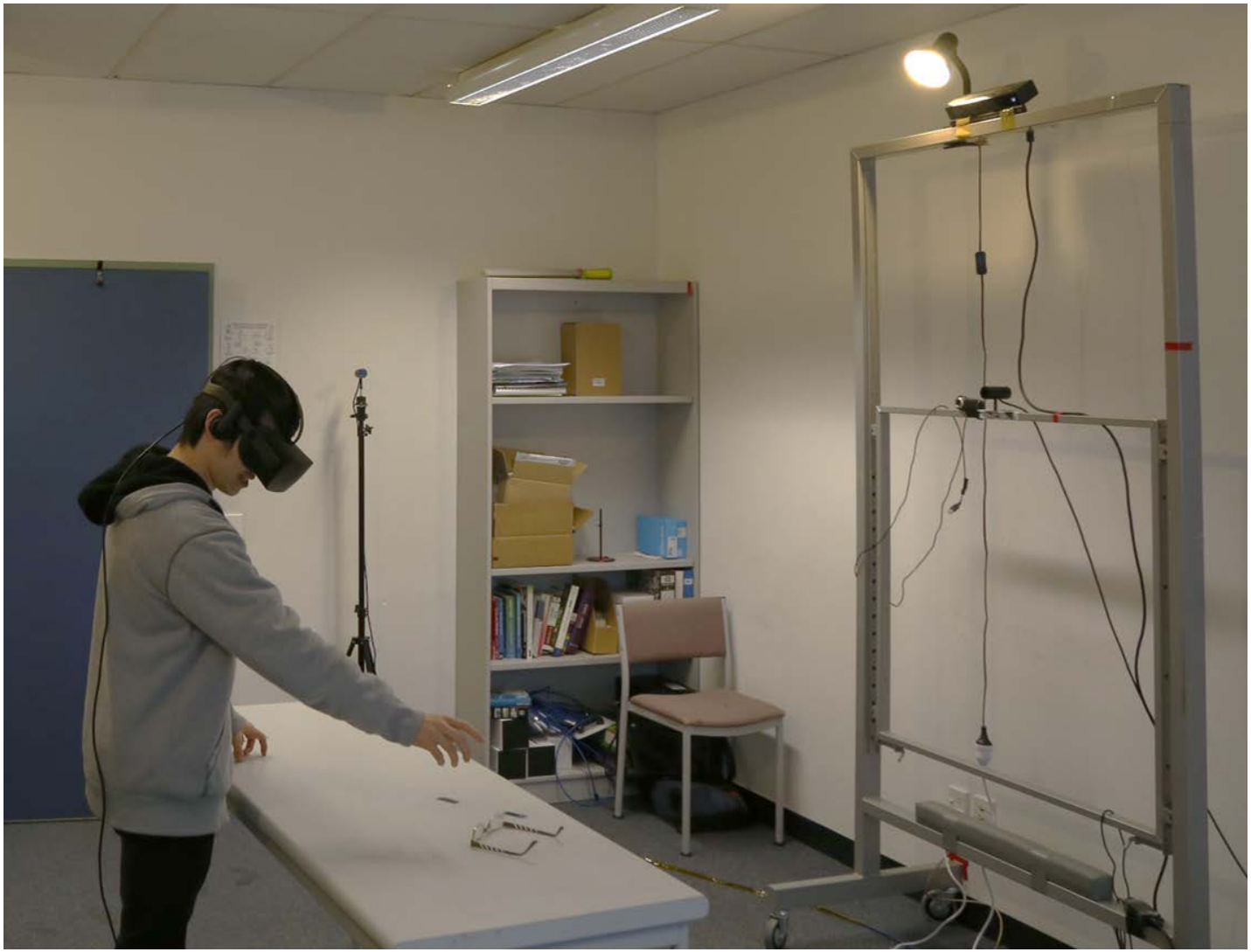
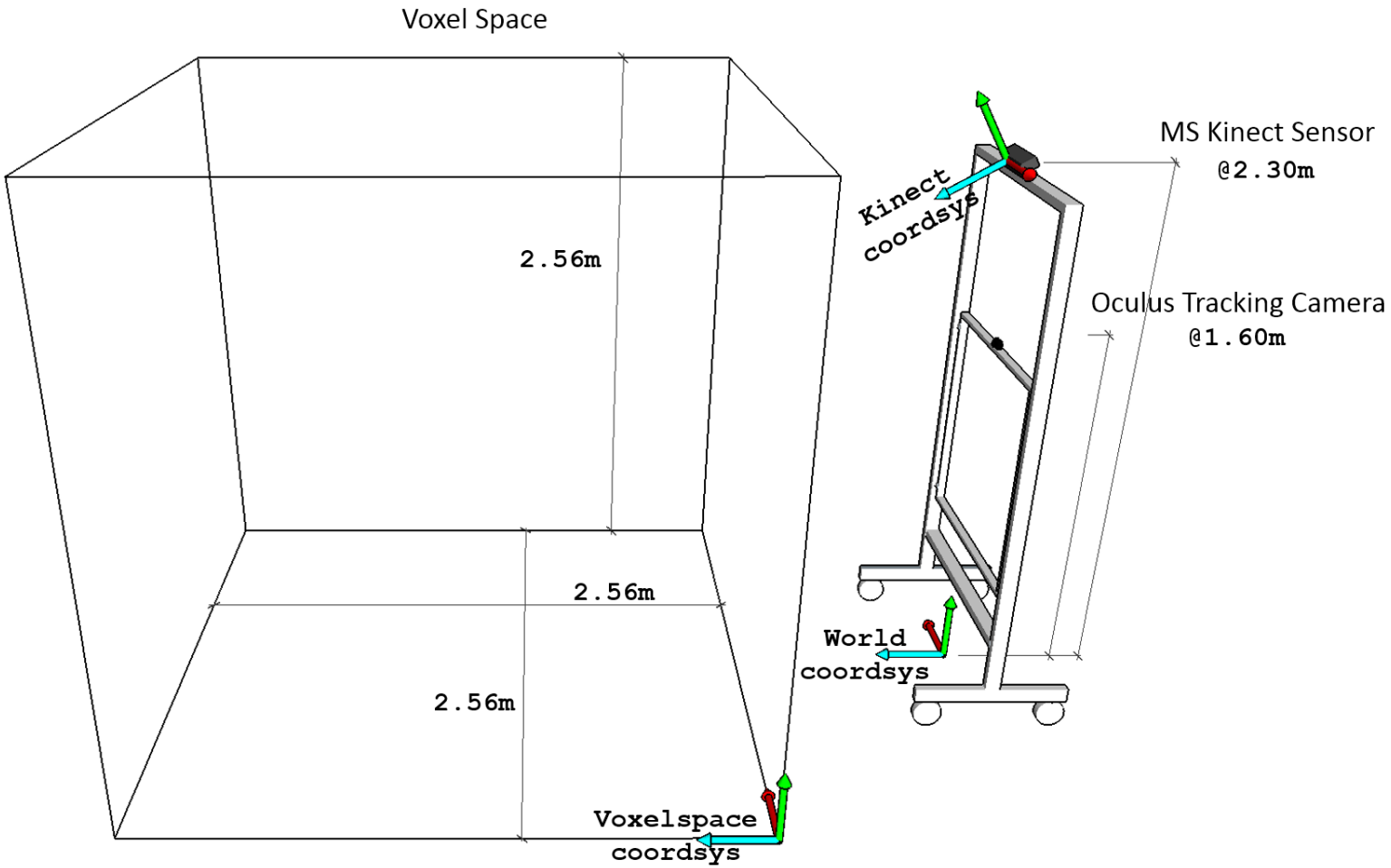
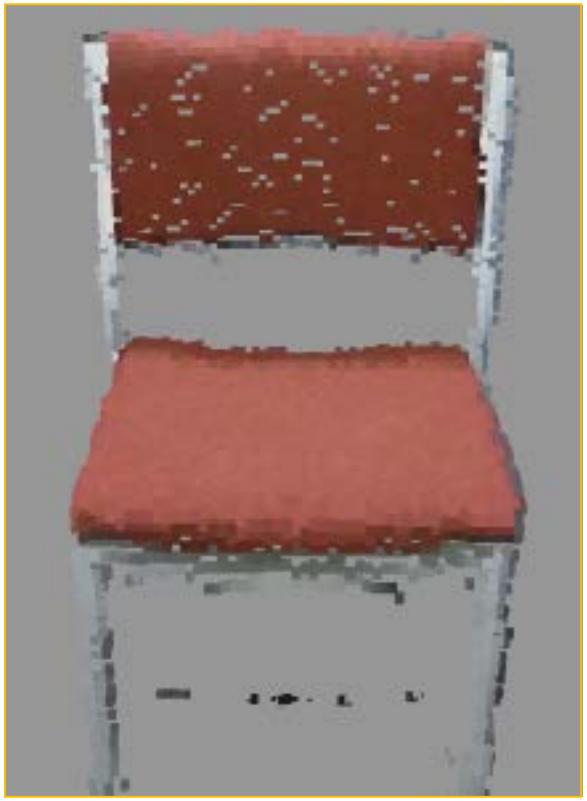
# Our IMR Voxelspace I



# Our IMR Voxelspace I



# Reality to Voxelspace



Regenbrecht, H., Meng, K., Reepen, A., Beck, S., & Langlotz, T. (2017, October). Mixed voxel reality: Presence and embodiment in low fidelity, visually coherent, mixed reality environments. In *2017 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)* (pp. 90-99). IEEE.

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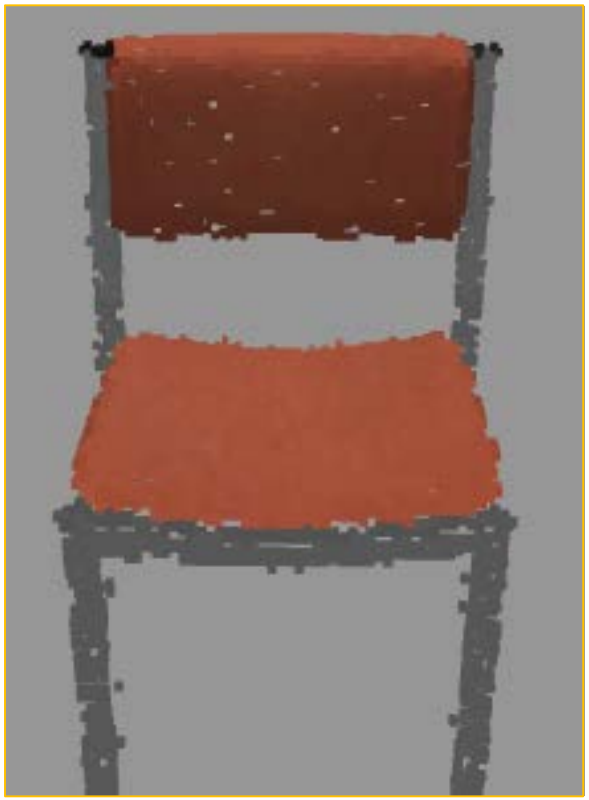
# CAD to Voxelspace



Regenbrecht, H., Meng, K., Reepen, A., Beck, S., & Langlotz, T. (2017, October). Mixed voxel reality: Presence and embodiment in low fidelity, visually coherent, mixed reality environments. In *2017 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)* (pp. 90-99). IEEE.

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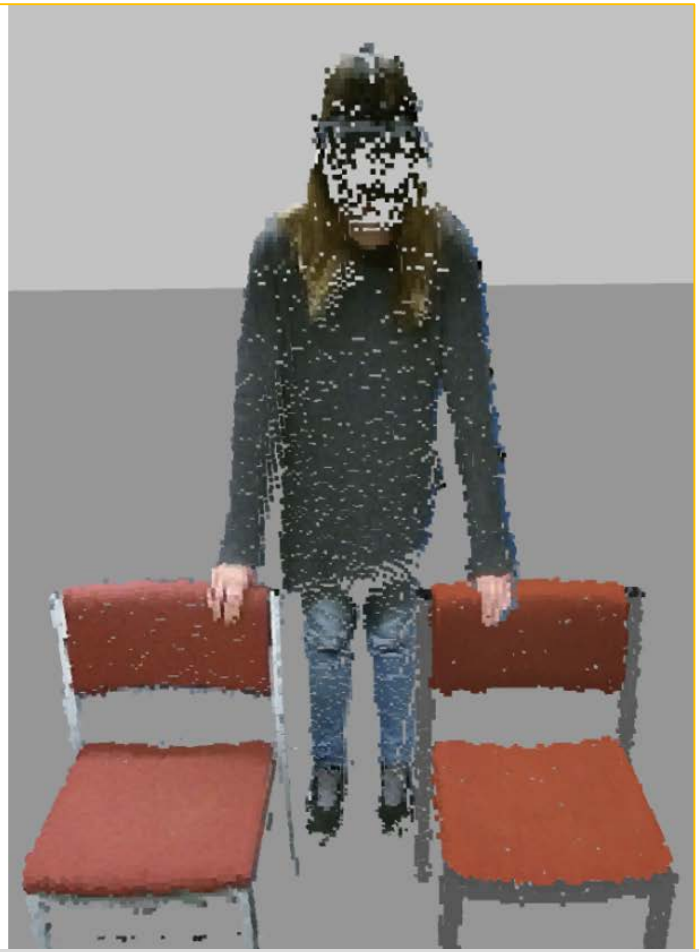
# Mixed Voxel Reality



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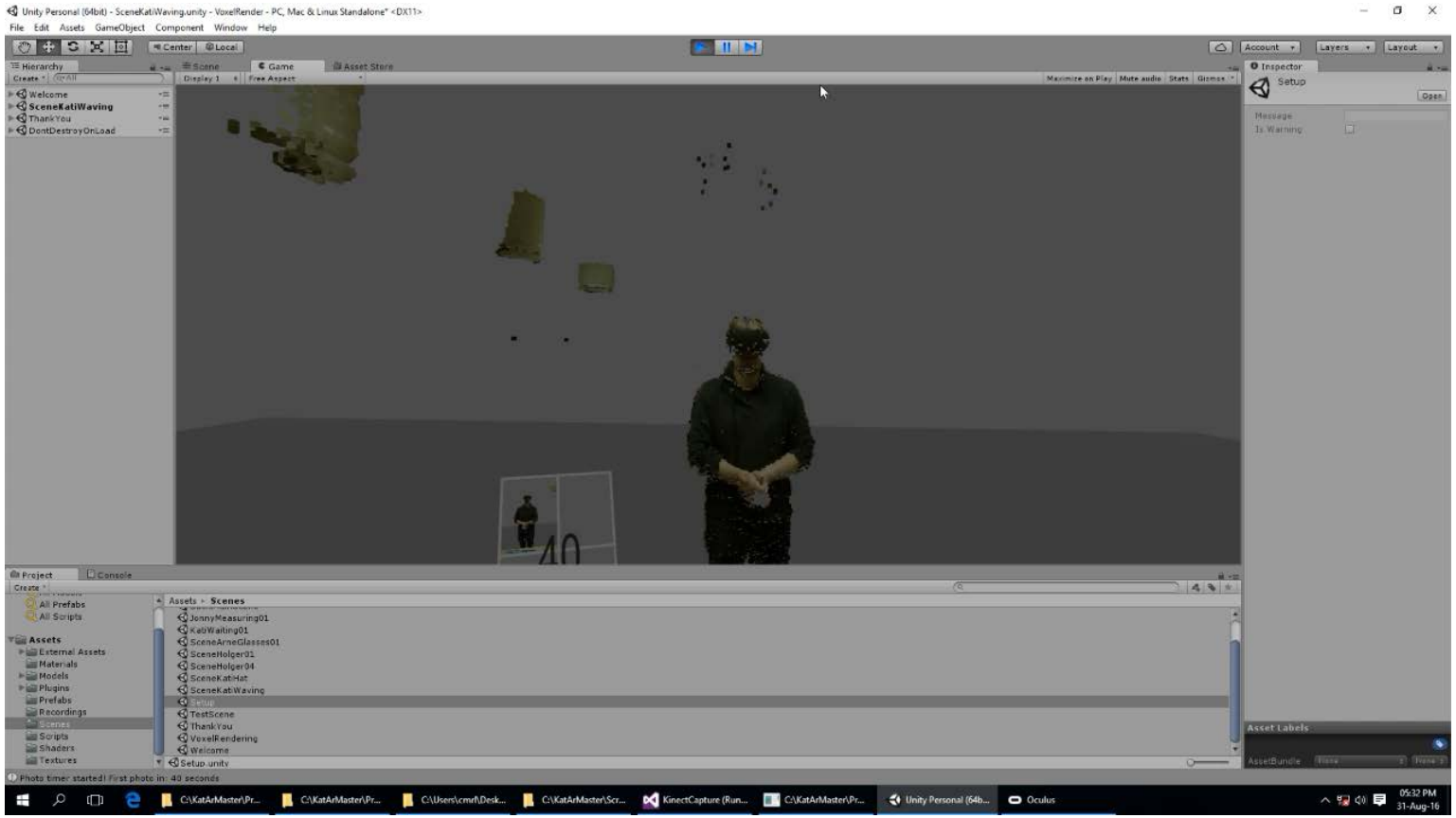
# Installation at Oslo Uni



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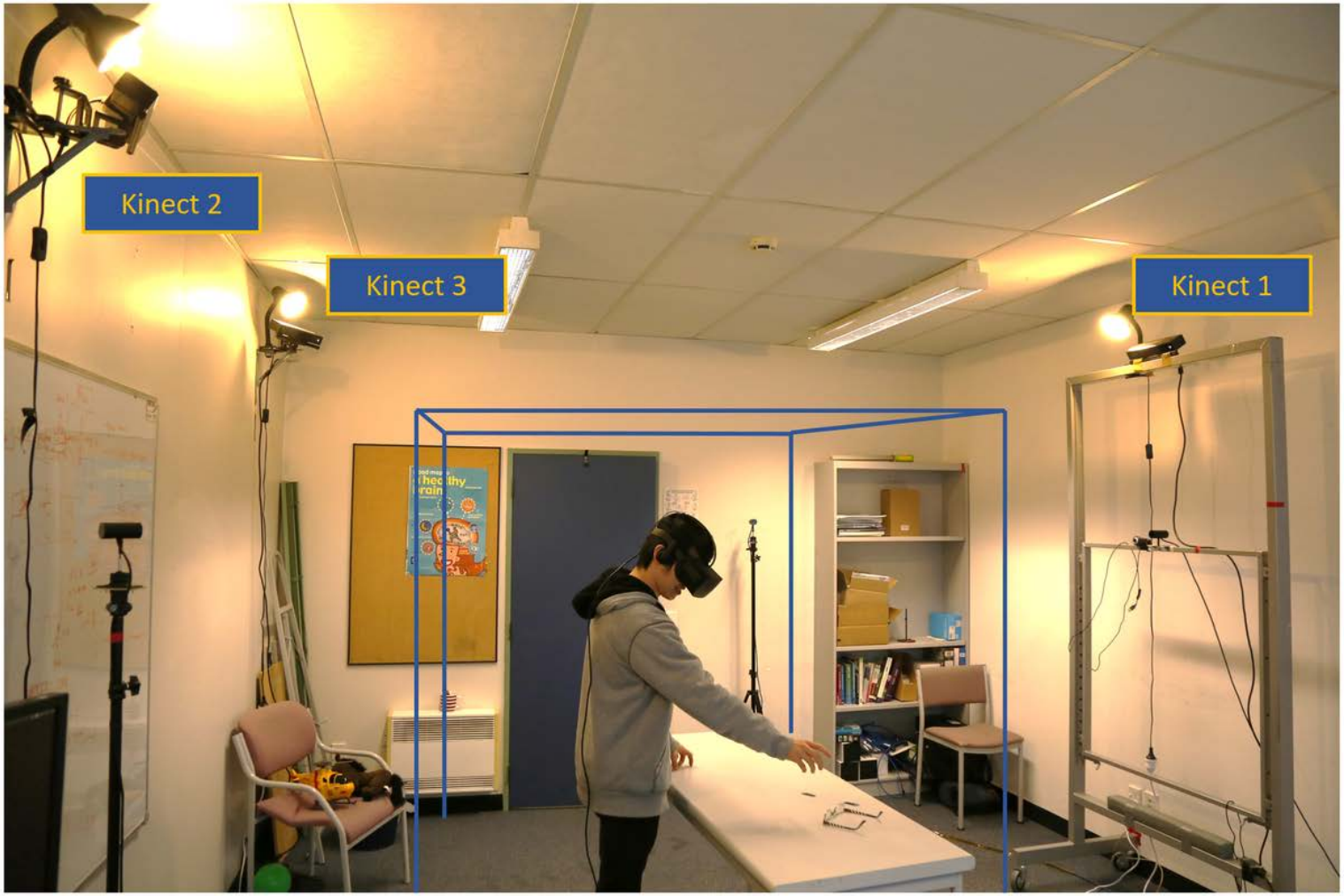
# Our IMR Voxelspace II



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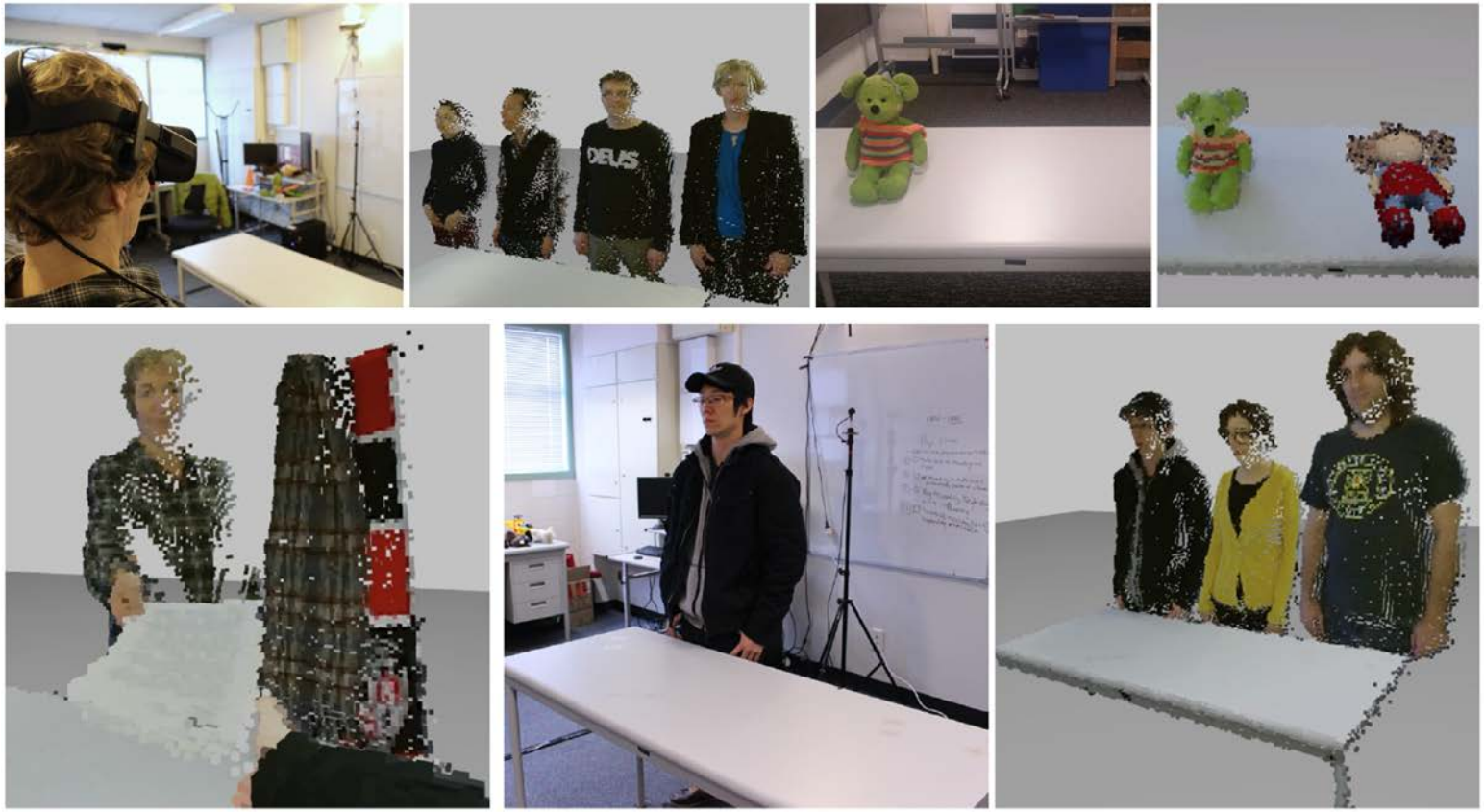
# Study on Effectiveness



Regenbrecht, H., Park, J. W. N., Ott, C., Mills, S., Cook, M., & Langlotz, T. (2019). Preaching voxels: An alternative approach to mixed reality. *Frontiers in ICT*, *6*, 7.

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# Volumetric Video

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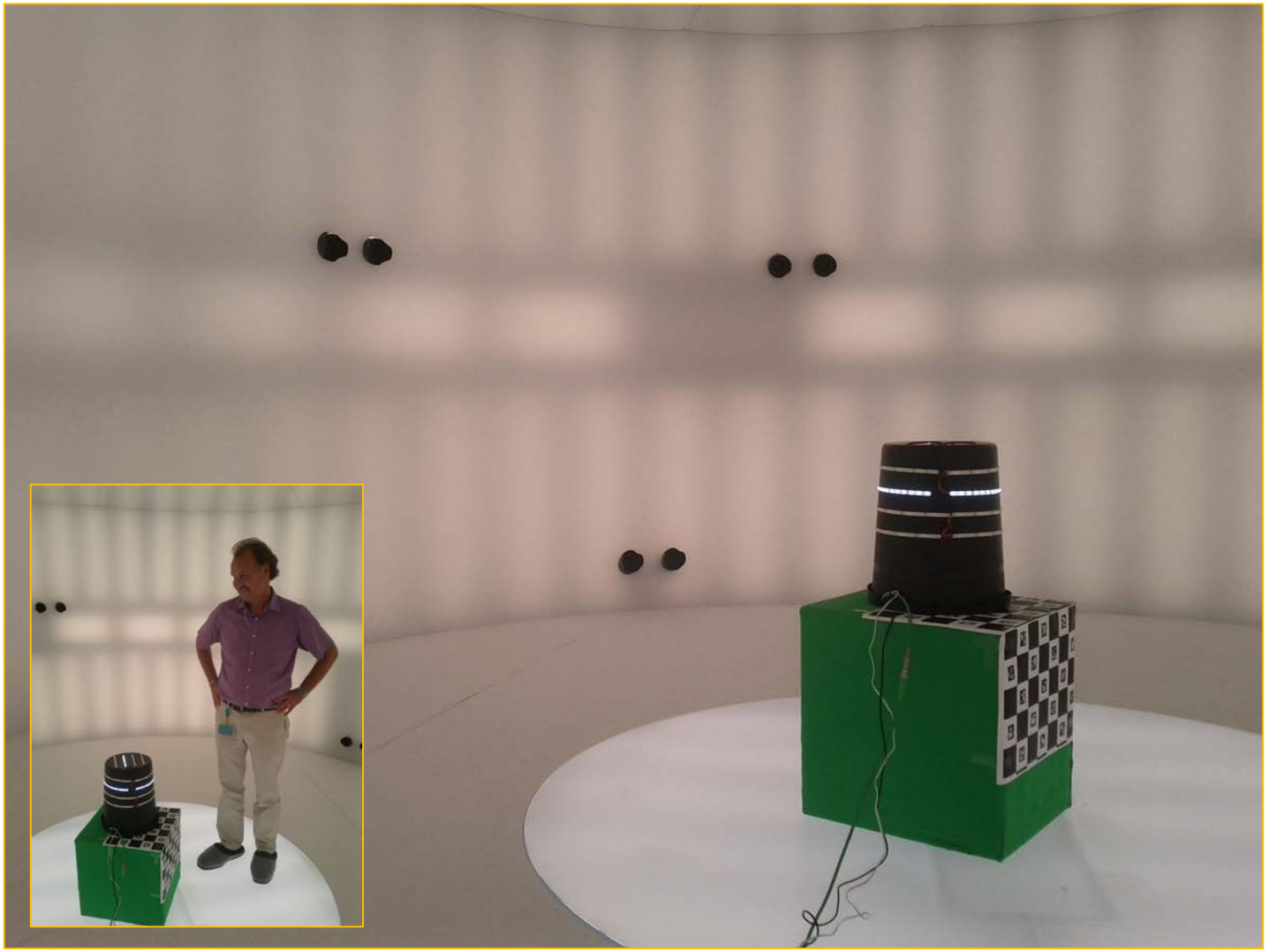
# Volucap (HHI Berlin)



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# Volucap (HHI Berlin)

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# Volucap (HHI Berlin)

- Production of high fidelity 3D movie assets
- Diffuse back-lit dome (individually controllable panels)
- 32 cameras (16 stereo camera pairs)
- Each pair connected to a dedicated high-end PC
- Hundreds of hours of post processing per minute of produced volumetric video
- about 1.5 TB/min for the meshed content

O. Schreer, I. Feldmann, T. Ebner, S. Renault, C. Weissig, D. Tatzelt, and P. Kauff. Advanced Volumetric Capture and Processing. SMPTE Motion Imaging Journal, 128(5):18–24, 2019.
O. Schreer, I. Feldmann, S. Renault, M. Zepp, M. Worchel, P. Eisert, and P. Kauff. Capture and 3d video processing of volumetric video. In 2019 IEEE International Conference on Image Processing (ICIP), 2019.

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# Mixed Reality Capture Studio (Microsoft)

© Microsoft

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# Mixed Reality Capture Studio (Microsoft)

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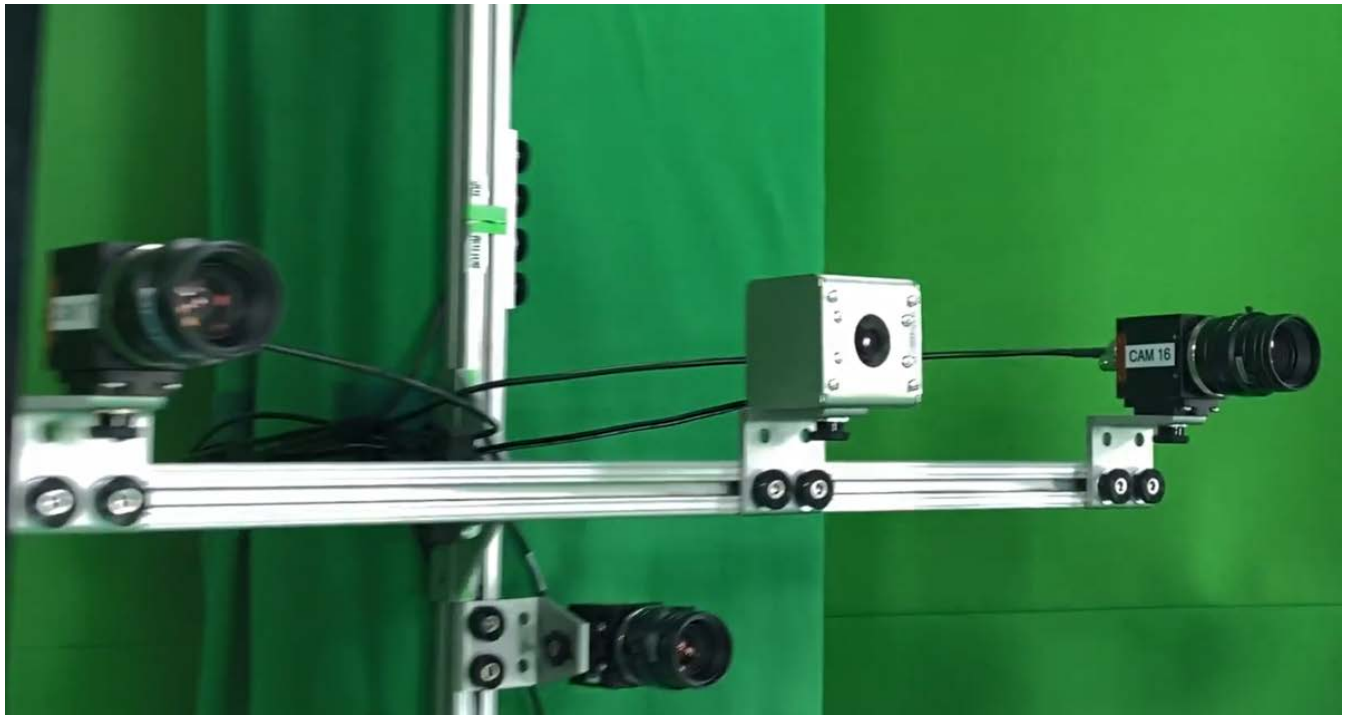
# Mixed Reality Capture Studio (Microsoft)

- 106 cameras
- raw footage 600GB/min,
- compressed to custom MP4 format at about 400MB/sec to 1.8GB/sec depending on the target device.



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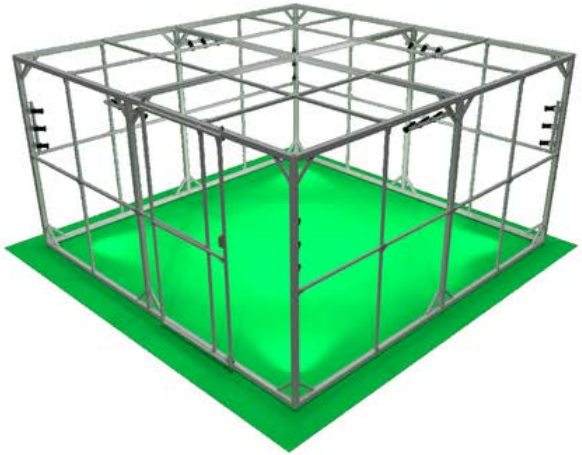
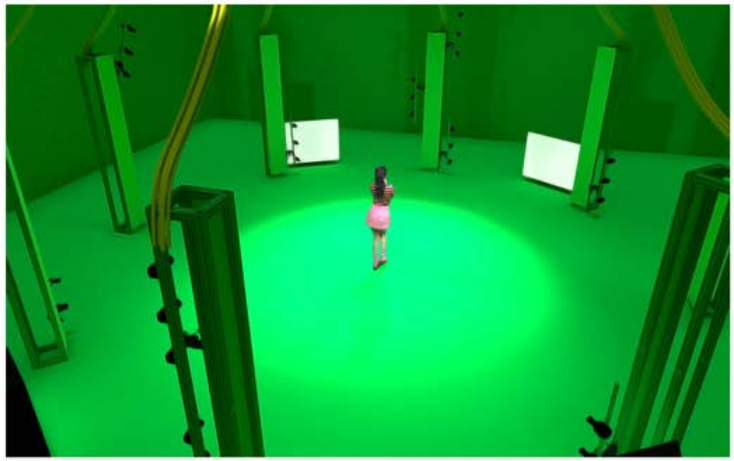
# 8i

# 8i



Portable Stage



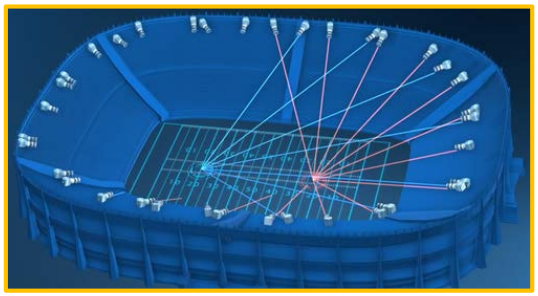
Premium Stage

## PRODUCT SPECIFICATIONS

| Portable Stage | Premium Stage |
|---|---|
| Build Volume: 4.9m(16ft) x 4.9m(16ft) x 2.4m(8ft) | Build Volume: 10m(32.8ft) x 10m(32.8ft) x 6.1M(20ft) |
| Capture Volume: 1.5m(4.9ft) Diameter x 2m(6.6ft) | Capture Volume: 2.5m(8.2ft) Diameter x 2.2m(7.2ft) |
| Number of Cameras: 30 | Number of Cameras: 30 |
| Camera Resolution: HD 1920 x 1080 | Camera Resolution:UHD 4096 x 3000 |
| Frame Rates: 15FPS, 30FPS | Frame Rates: 15FPS, 30FPS |

# True View (Intel)

- Volumetric reconstruction of an entire sports field
- (up to) 38 5K stationary mounted cams
- multiple high-performance on-site servers connected over fiber



https://www.intel.com/content/www/us/en/sports/nfl/overview.html
I. T. View. Get closer to the game with intel true view, 2017

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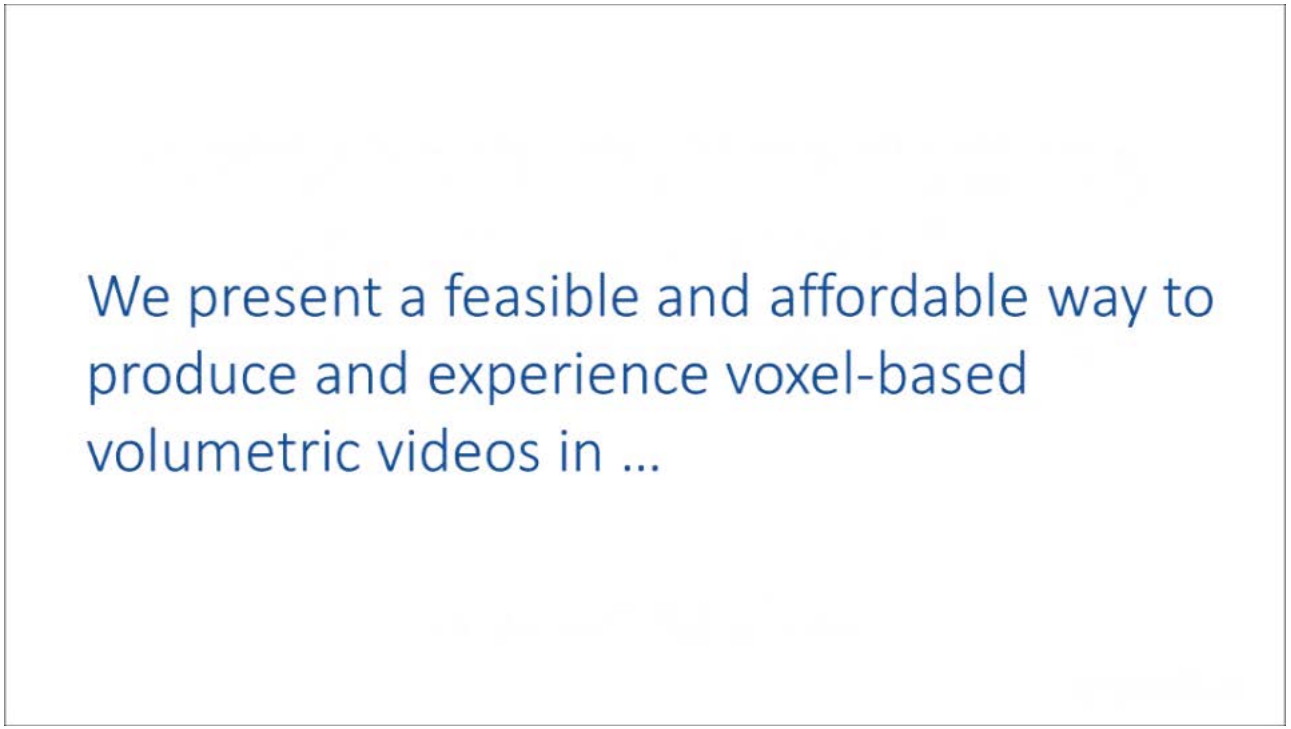
# Voxelvideo




Regenbrecht, H., Ott, C., Park, J. W. N., Duncan, S., and Collins, J.(under review). Voxelvideos for Entertainment, Education, and Training.

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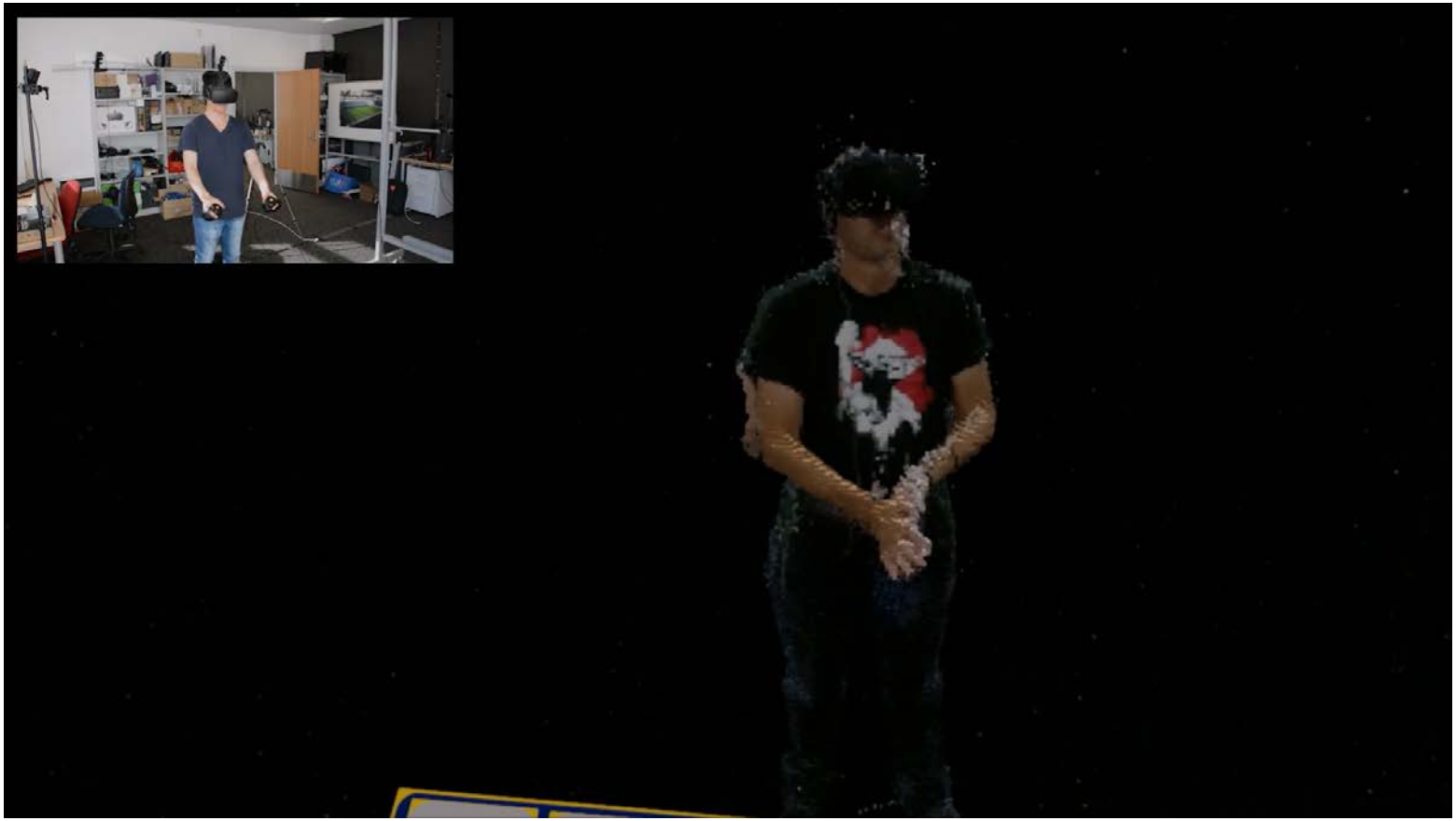
# Voxelvideo: Ātea Storytelling



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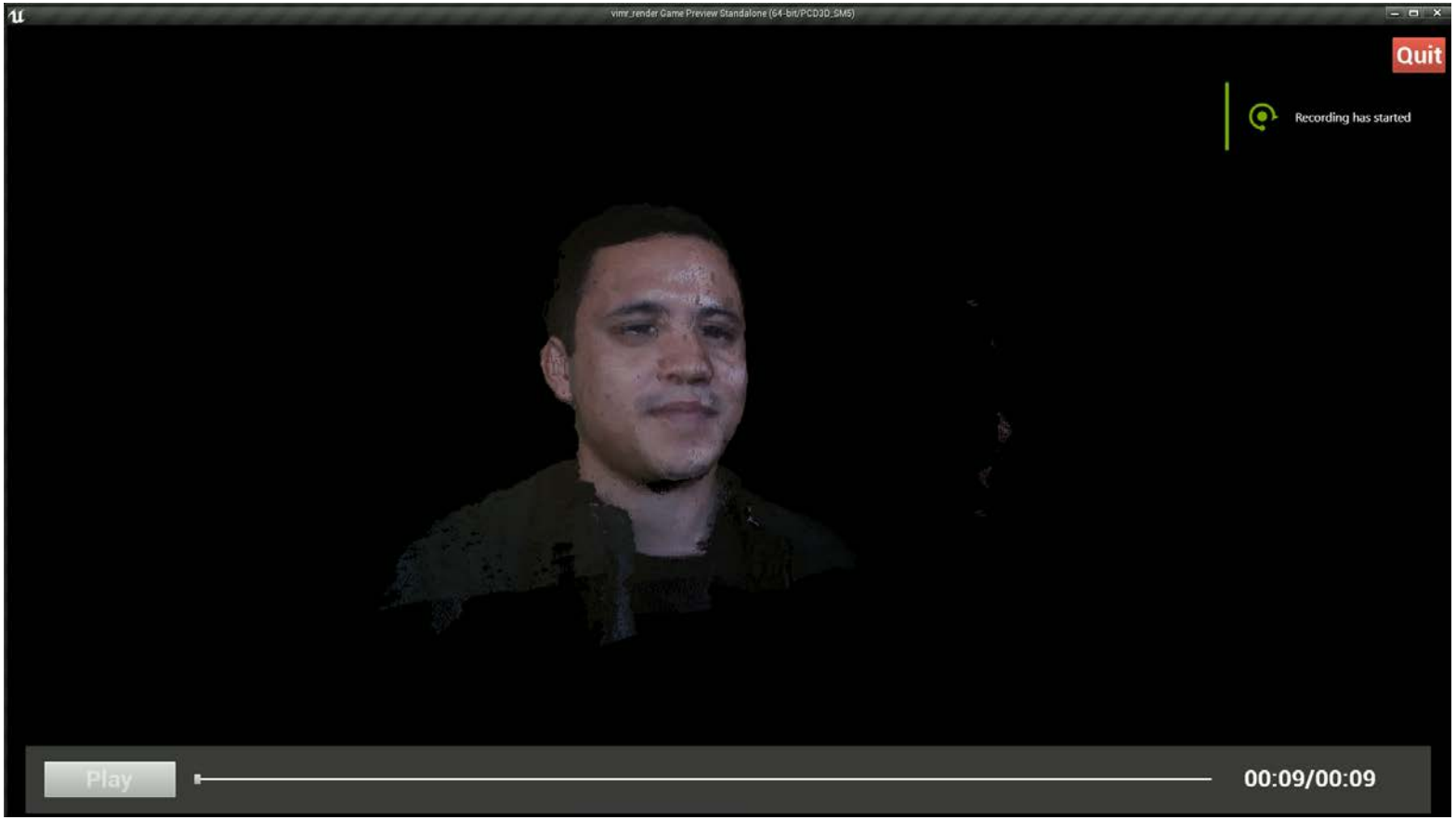


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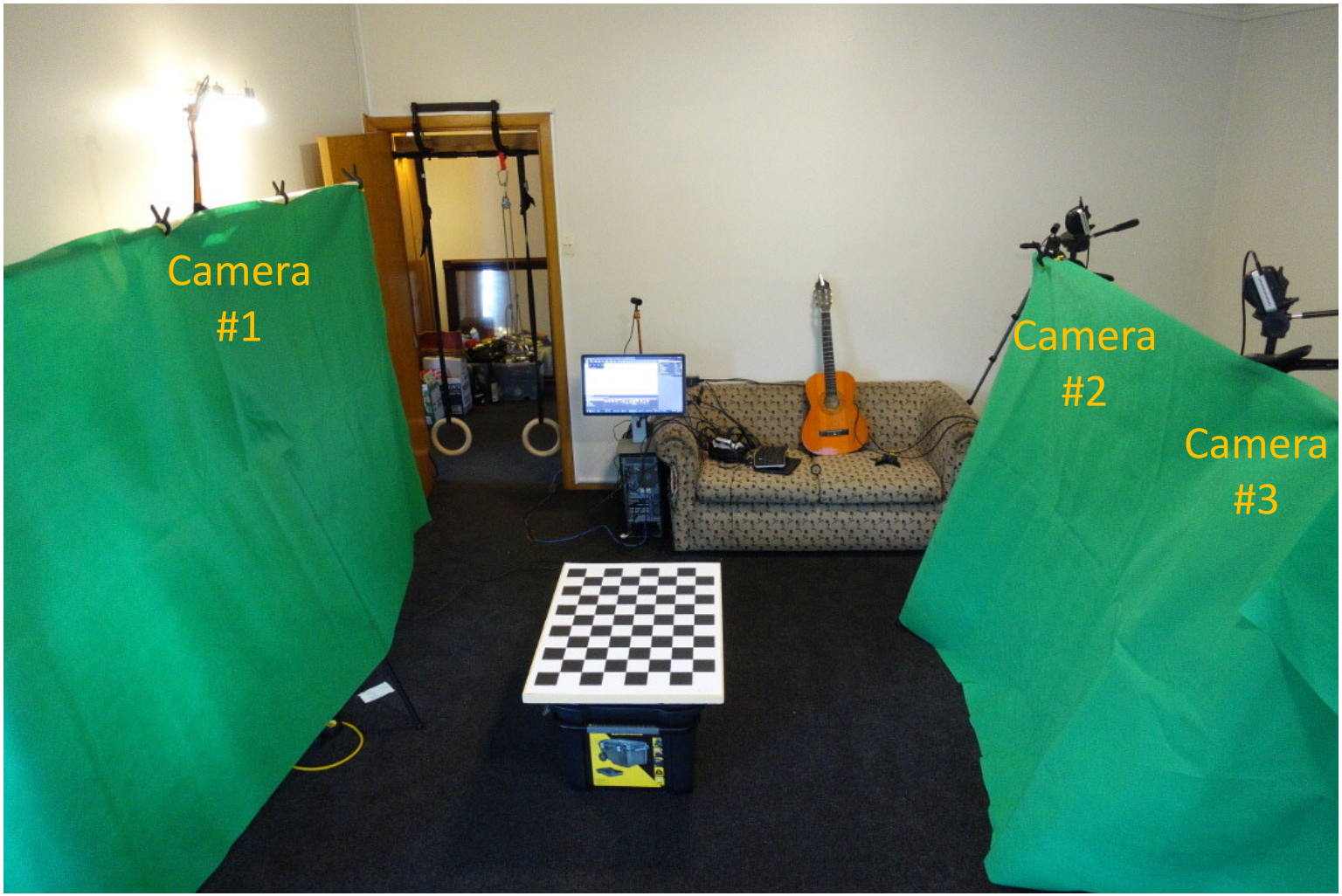


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# Voxelvideo

## Rosa and Stu at St Clair Beach Dunedin this morning

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# Volumetric Tele-Copresence

# “Holoportation”


Orts-Escolano, S., Rhemann, C., Fanello, S., Chang, W., Kowdle, A., Degtyarev, Y., ... & Tankovich, V. (2016, October). Holoportation: Virtual 3d teleportation in real-time. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (pp. 741-754).

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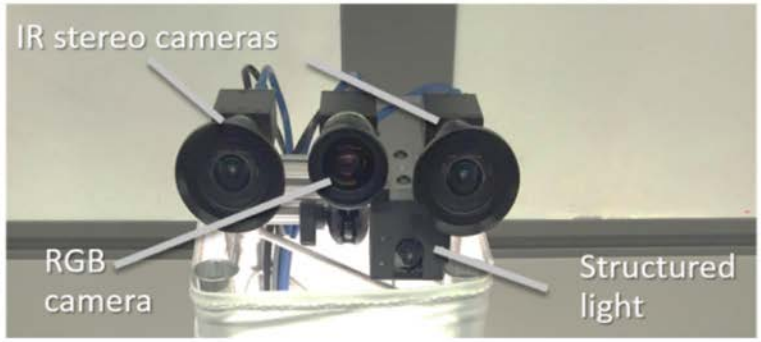
# “Holoportation”

Holoportation Rig

Trinocular Pod




- 8 camera “pods”, each w/ 3 cameras (= 24 4MP cameras per site) @ 30fps
- 15cm stereo baseline => avg error 3mm @ 1m (6mm @ 1.5m)
- Transmission over 10 Gbps network (2MB per frame for mesh geometry (60K vertices, 40K triangles))
- 4 PCs (handling two pods each) w/ 2 GPU cards eachplus one fusion machine (same spec) per site

Orts-Escolano, S., Rhemann, C., Fanello, S., Chang, W., Kowdle, A., Degtyarev, Y., ... & Tankovich, V. (2016, October). Holoportation: Virtual 3d teleportation in real-time. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (pp. 741-754).

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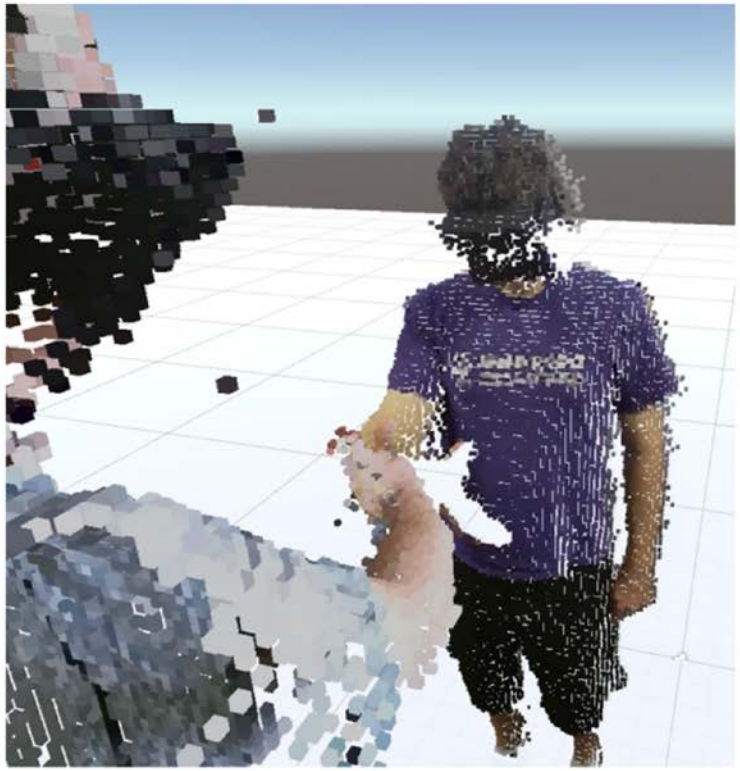
# Tele-Copresence




Regenbrecht, H., Park, J. W. N., Ott, C., Mills, S., Cook, M., & Langlotz, T. (2019). Preaching voxels: An alternative approach to mixed reality. *Frontiers in ICT*, *6*, 7.

Park, N. J., & Regenbrecht, H. (2019). Resolutions and Network Latencies Concerning a Voxel Telepresence Experience. Journal of Software Engineering and Applications, 12(05), 171-201.

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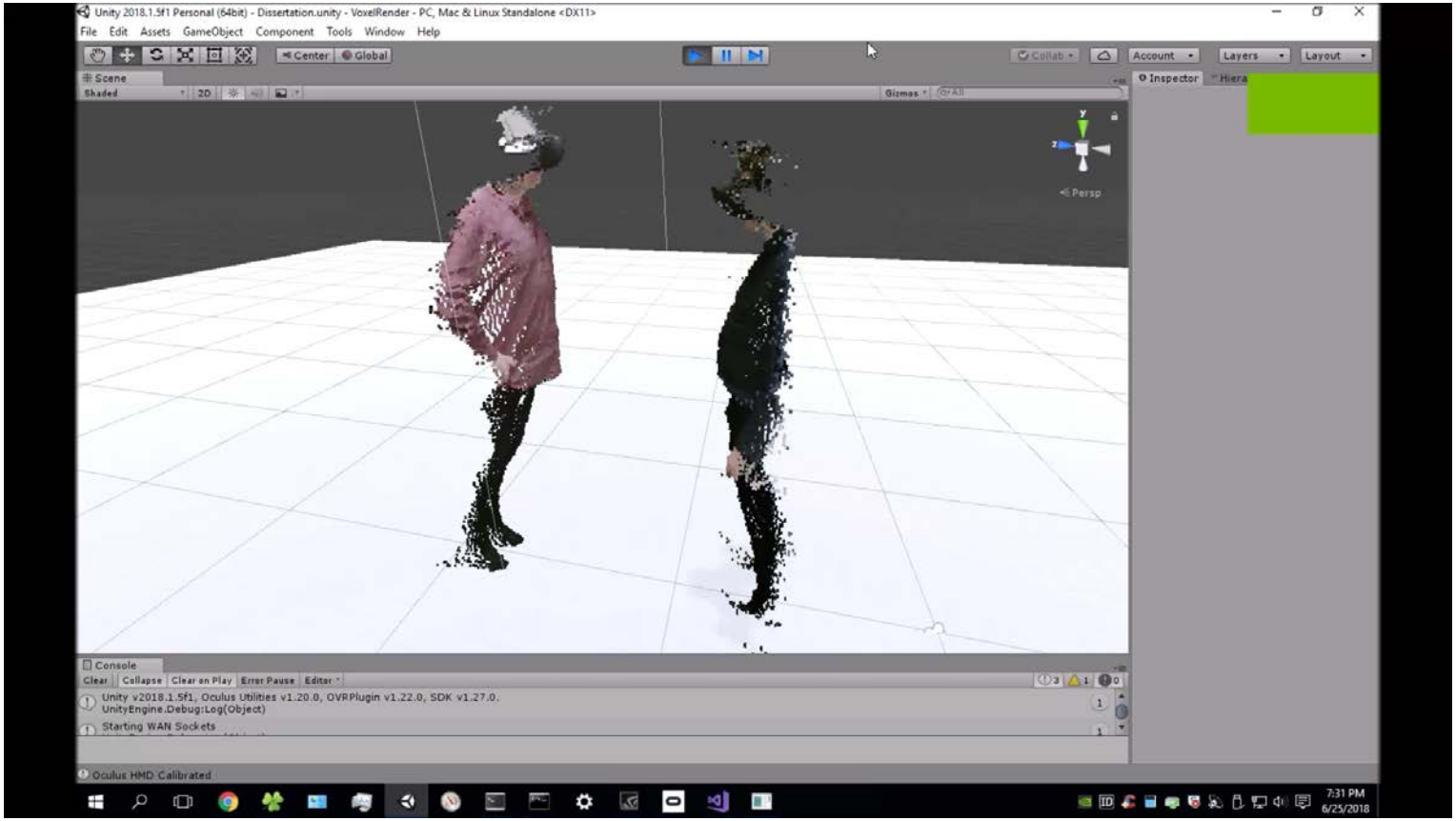
# Tele-Copresence (Dunedin/NZ – London/UK)

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# Telepresence

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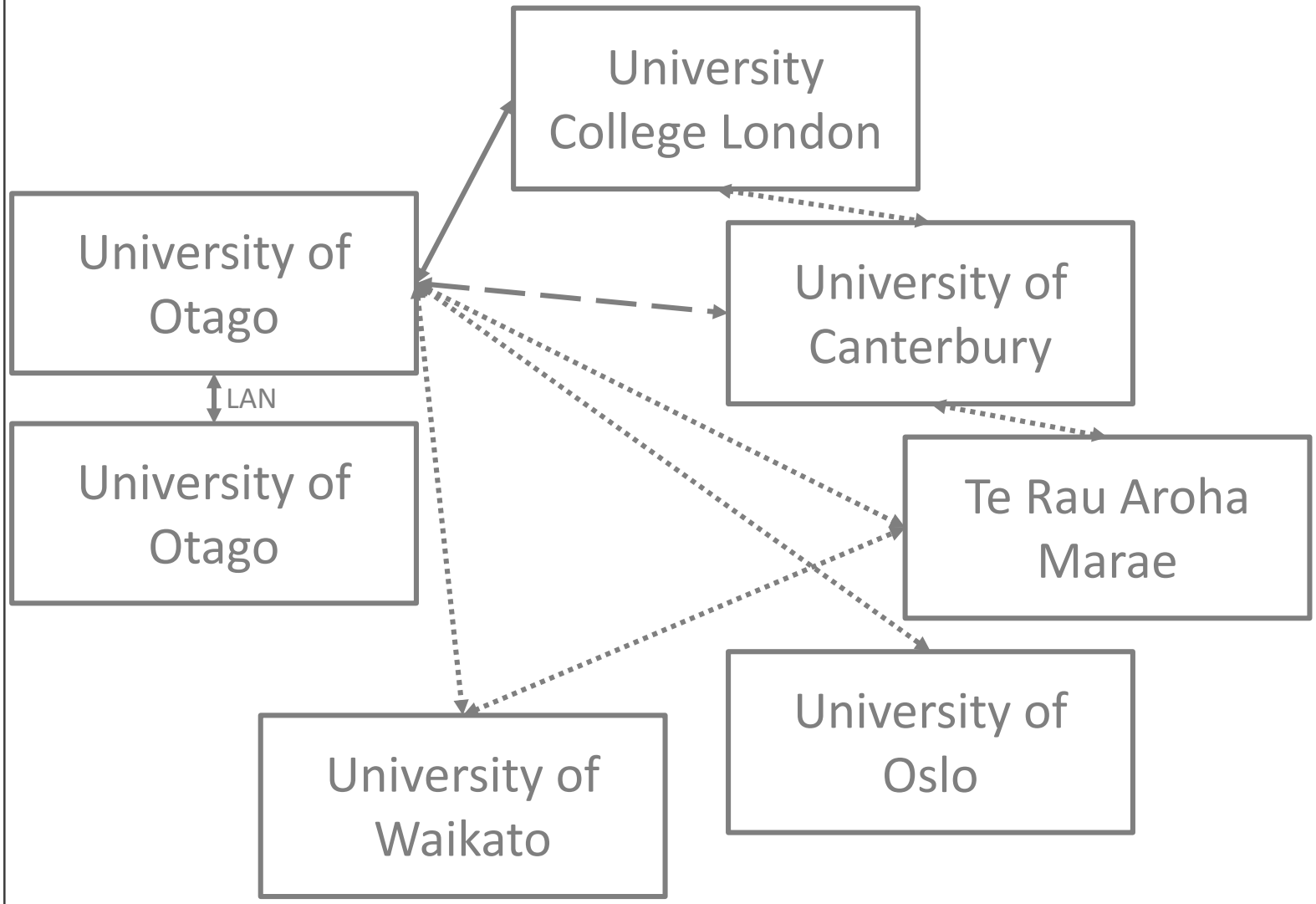
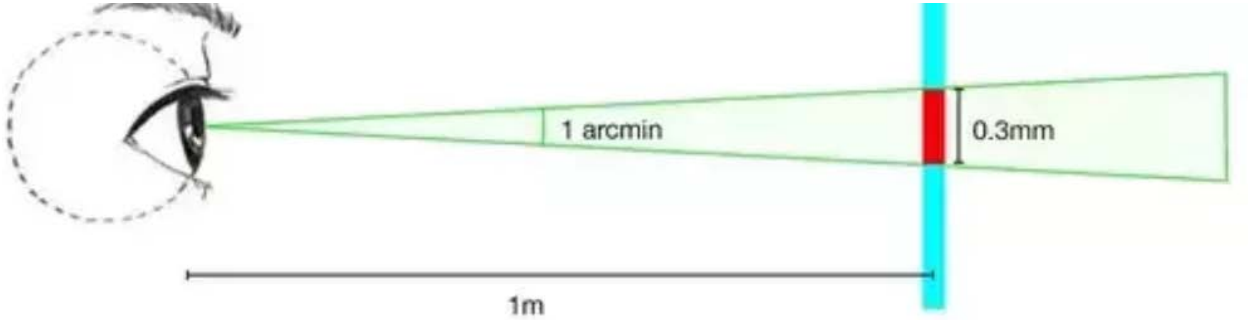
# 3D Telepresence Evaluation

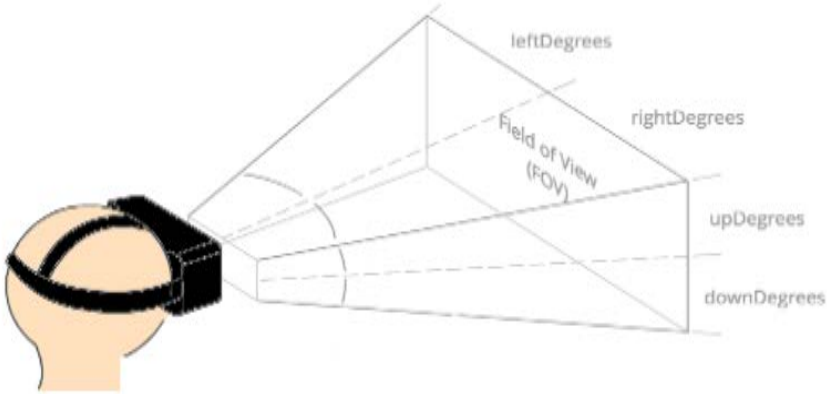


# “Ideal” Voxel Resolution




0.25mm

www.quora.com




2mm
1m at 1m w/ 2K pixels

0.5mm
2m at 1m w/ 4K pixels

www.ist.ucf.edu

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# Latency

- theoretical minimum latency based on c:
  - 1,000 km -> 6,7 milliseconds
  - 10,000 km -> 67 milliseconds
- practical “ping” latency about 2 x theoretical
  - 1,000 km -> 13 milliseconds
  - 10,000 km -> 135 milliseconds
- => Dunedin – Sydney
  27ms (one way)
- => Dunedin – London
  240ms (one way)

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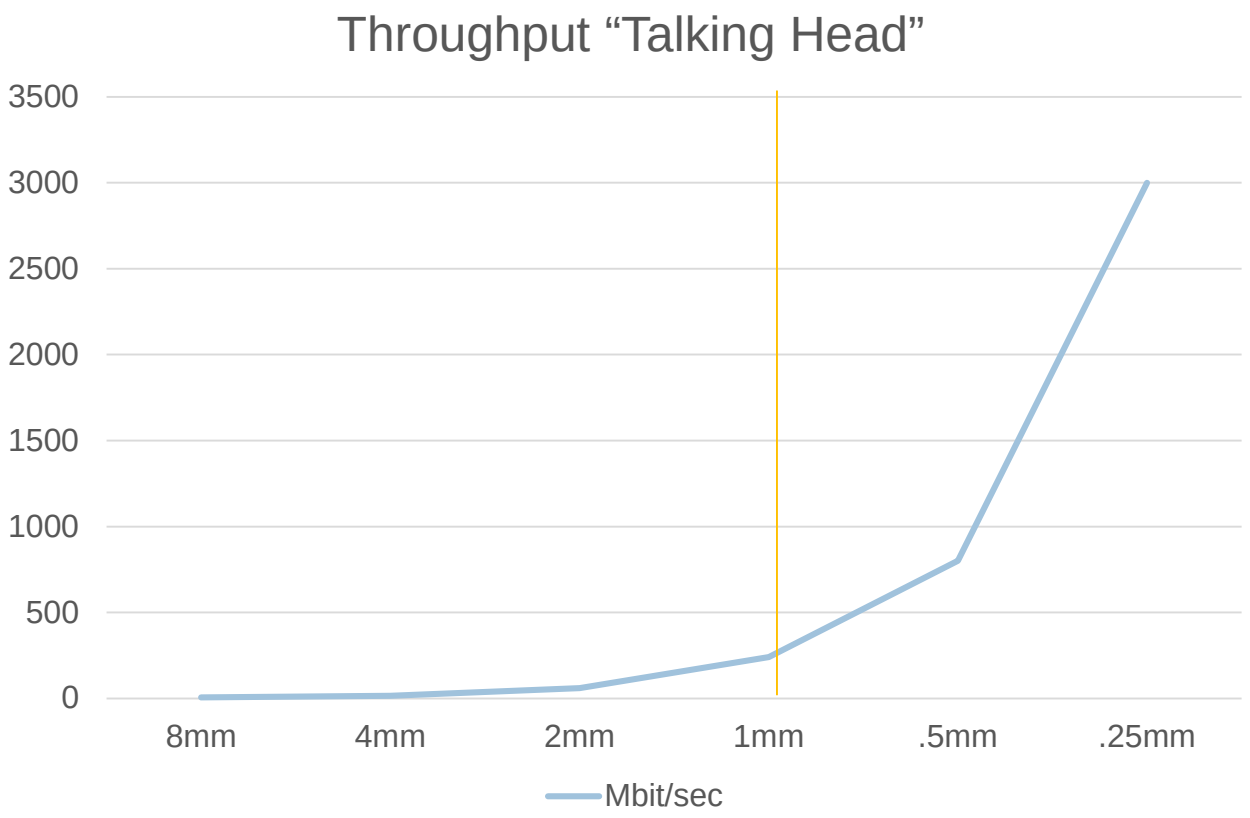
# Voxel Throughput



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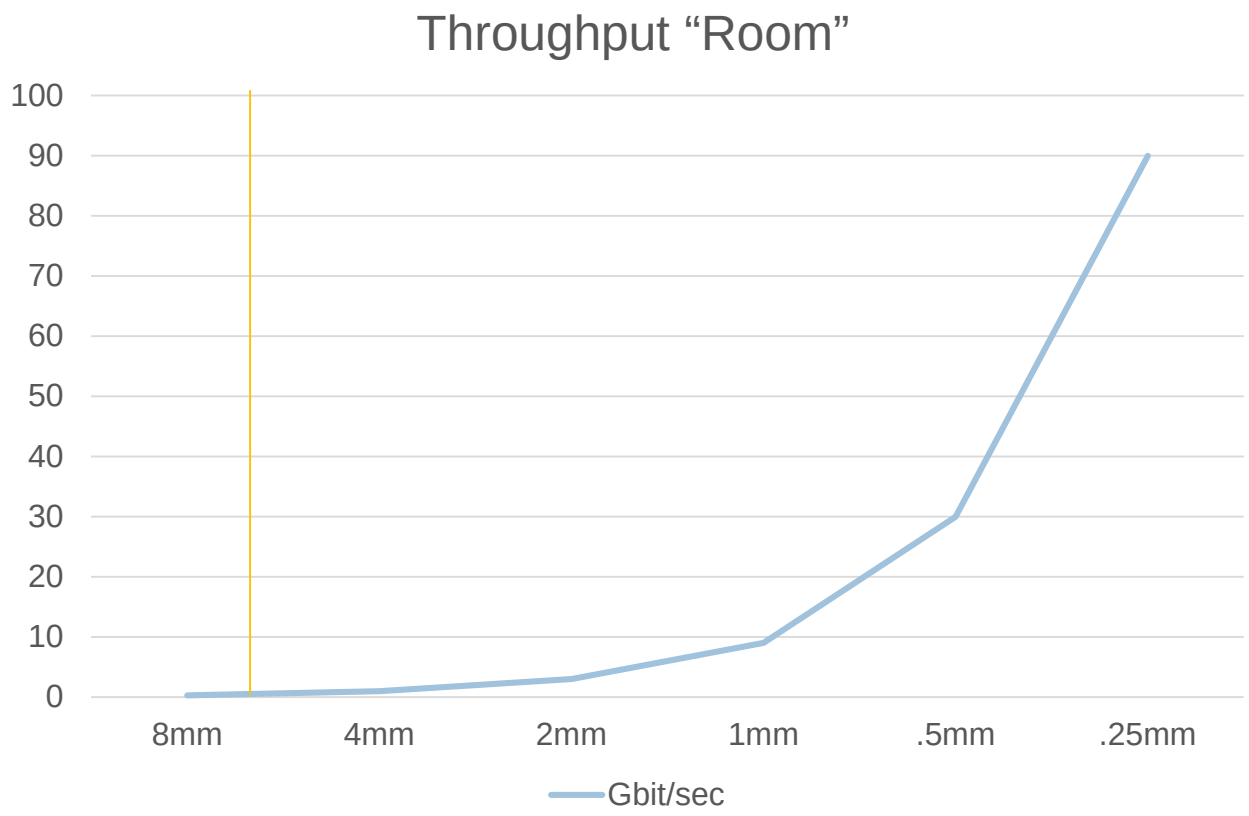
# Voxel Throughput



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# Summary

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# Summary

- we do not need always high-res, as long as experience is believable and coherent
- nevertheless, we will work on high-res (count on Moore's law)
- voxels are the logical next step after pixels

2D
(vectors)
-
Pixels


3D
(triangles)
-
Voxels

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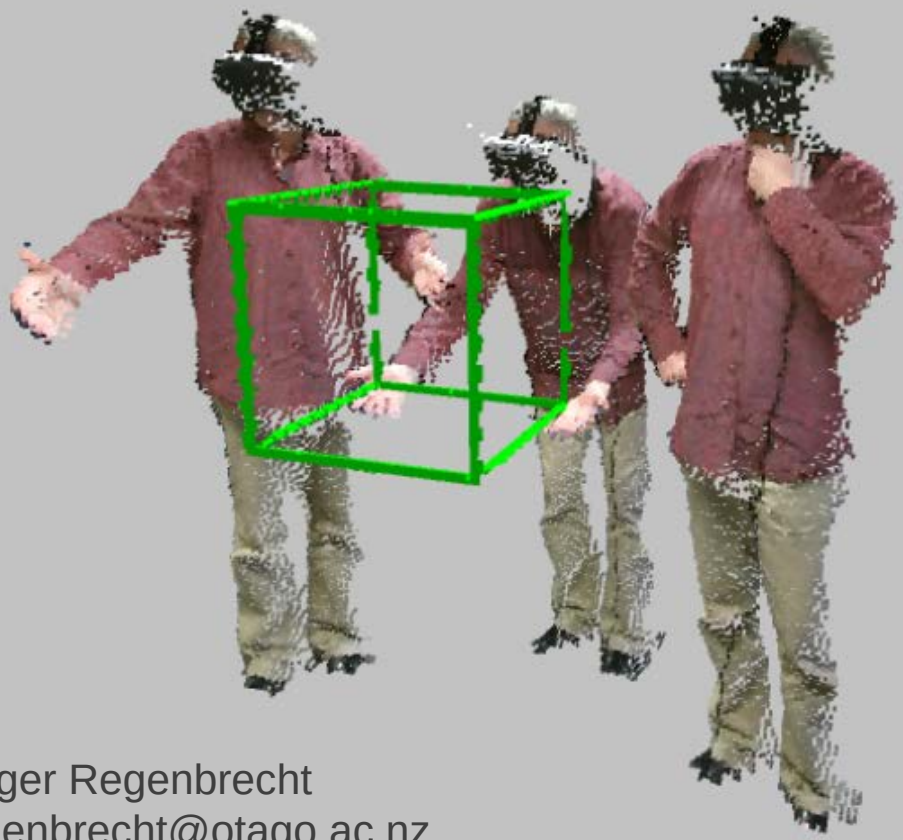
# Contact (for this lecture)



Holger Regenbrecht
holger.regenbrecht@otago.ac.nz

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# MISC

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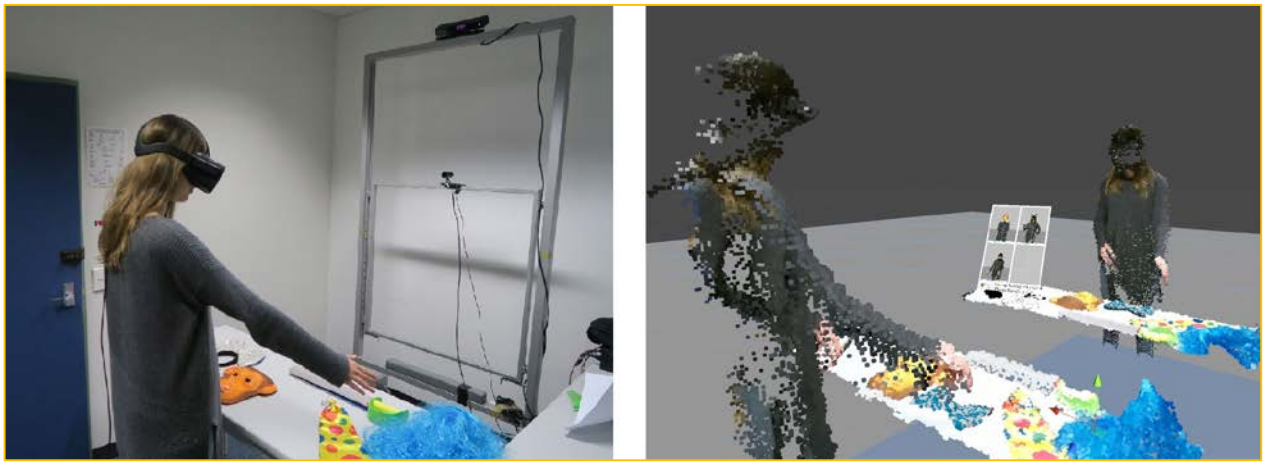
# Mixed Voxel Reality w/ Mirror



Regenbrecht, H., Meng, K., Reepen, A., Beck, S., & Langlotz, T. (2017, October). Mixed voxel reality: Presence and embodiment in low fidelity, visually coherent, mixed reality environments. In *2017 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)* (pp. 90-99). IEEE.

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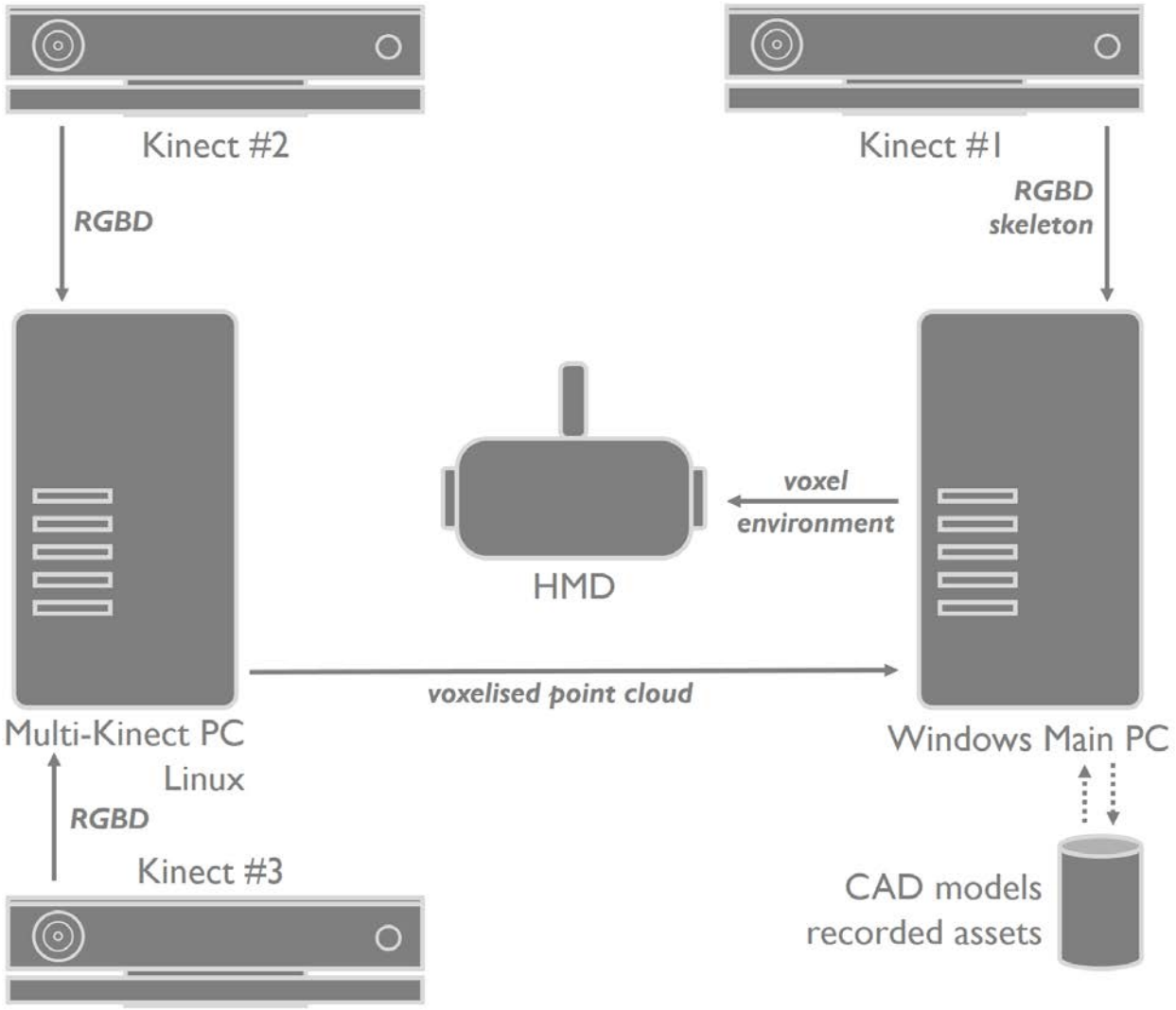
# Our IMR Voxelspace II

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# Social Psychology Study

Ruffman, T., Ruffman, C., Hill, S., Turunc, G., Park, N., Du, K., ... & Philipp, M. C. (2020). RWAc and SDOc: The measurement of right-wing authoritarianism and social dominance orientation in childhood. *Social Development*.

# Body Perception Study

OK, actually a dense point cloud

Nimcharoen, C., Zollmann, S., Collins, J., & Regenbrecht, H. (2018, October). Is That Me?—Embodiment and Body Perception with an Augmented Reality Mirror. In *2018 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)* (pp. 158-163). IEEE.

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# Resolution and Latency Study

Park, N. J., & Regenbrecht, H. (2019). Resolutions and Network Latencies Concerning a Voxel Telepresence Experience. *Journal of Software Engineering and Applications*, *12*(05), 171.

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# Volucap (HHI Berlin)