AR/VR Renaissance:
opportunities, pitfalls, problems


The New York Times

A Virtual Reality Revolution, Coming to a Headset Near You

By LORNE MANLY NOV. 19, 2015

Viktor Koen

Virtual reality — once the stuff of science fiction — is still in its infancy. But there's already a gold rush around the technology, which plunges viewers

Henry Fuchs

UNC & TU Wien

2017.12.12

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Outline

1. Promise, Pitfalls
2. Earliest promise: VR 49 years ago (1968)
3. Previous Boom 1990s
4. What's different now: enough money to develop technology
5. Remaining technical problems
   - Samples of progress
6. Is there a compelling application ? Social VR aka Telepresence
   - Samples of progress
7. Conclusions

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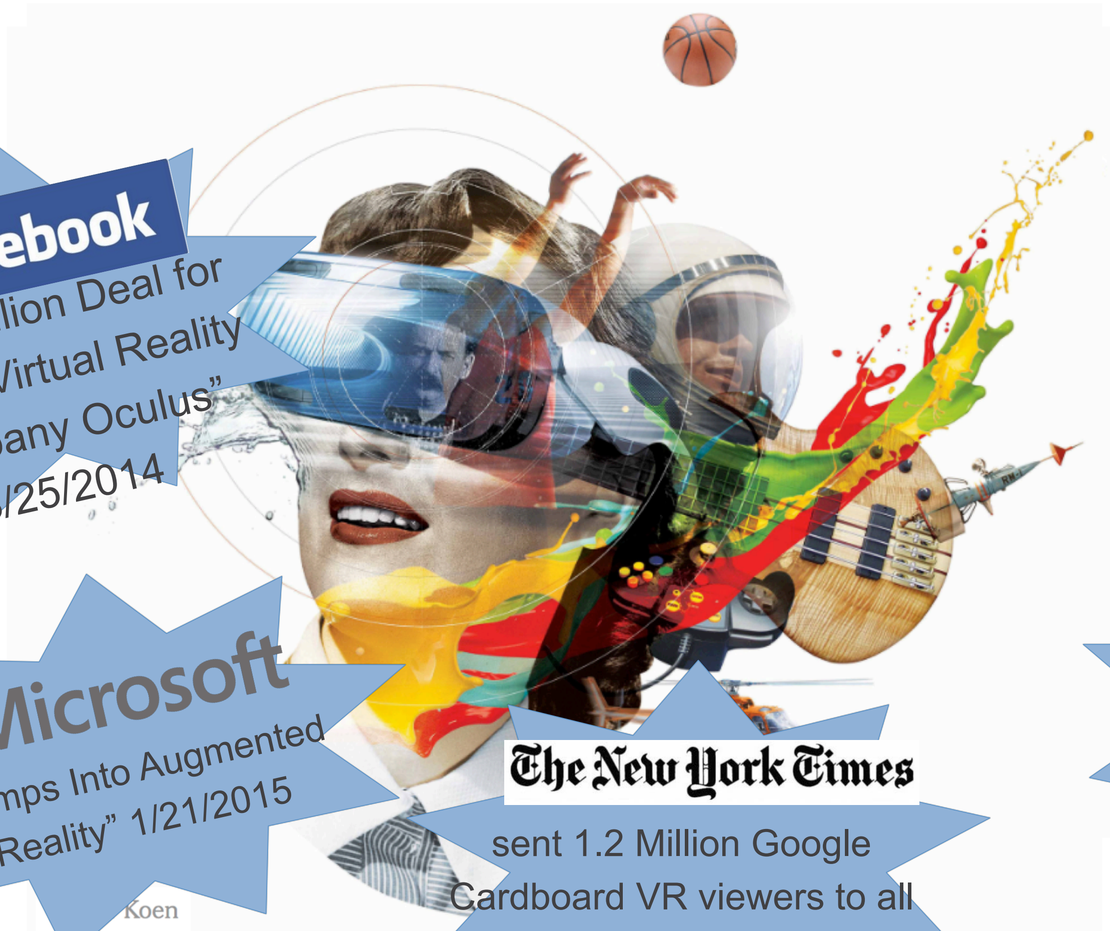


Koen

facebook
"$2 Billion Deal for startup Virtual Reality Company Oculus"
3/25/2014

Google
"Google and others invest $542M in 25% Augmented Reality startup Magic Leap"
10/22/2014

Microsoft
"Jumps Into Augmented Reality" 1/21/2015

PlayStation
Sony PlayStation VR

The New York Times
sent 1.2 Million Google Cardboard VR viewers to all Sunday subscribers
11/8/2015

Virtual reality — once the stuff o[...] is still in its infancy. But there's already a gold rush aroun[d] the technology, which plunges viewers into a simulated 3-D environment and lets them explore their surroundings as if they were really there.

Promises

“Annual shipments of VR headsets are set to surpass 12 million units in 2017 and will likely see strong growth through 2022 — when annual shipments will reach about 55 million.” ,”

businessinsider.com 2017.01.17

“Pretty soon we’re going to live in a world where everyone has the power to share and experience whole scenes as if you’re just there, right there in person.”

Mark Zuckerberg, Facebook CEO, 2016.02

The Pittfalls

Expectations unfulfilled, disappointments,

followed by mass exodus from the field,

then "Whatever happened to Virtual Reality?" C Sims, MIT Tech Review, Oct. 2010

Why would expectations be unfulfilled?

Technology not good enough for mass adoption.

What is that technology?

Let's go back to basics, to the beginning of VR

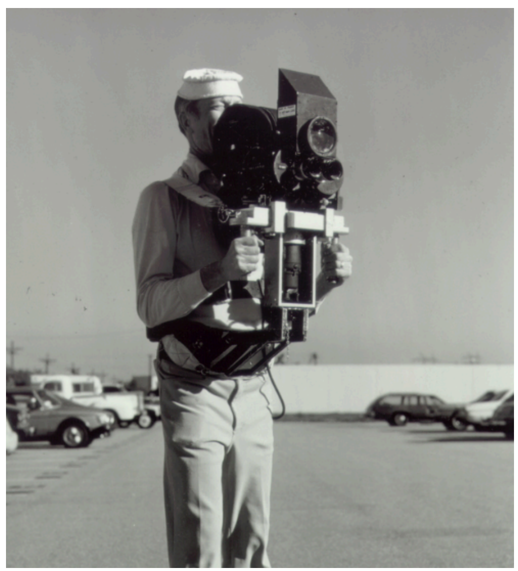
First Head-Mounted Display & Precursor: Morton Heilig

Sensorama (1957-1962)

1. Riding a motorcycle
2. Stereo views, audio (film)
3. Vibration
4. Smells

Telesphere Mask (1962)

1. Stereo views, wide FOV (TV)
2. Stereo audio
3. Smells

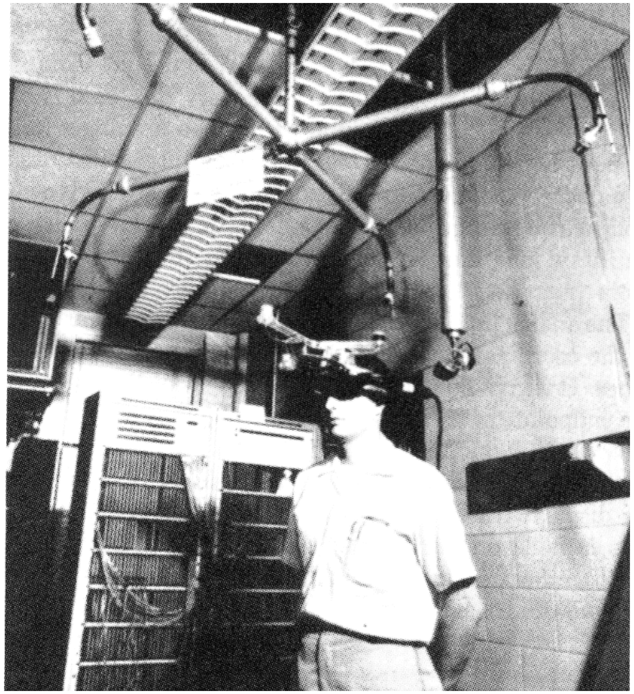


mortonheilig.com and thanks to Gerd Hesina

First AR/VR System: Ivan Sutherland (1968)

Sutherland, Ivan "A Head-Mounted Three-Dimensional Display" 1968 Fall Joint Computer Conference

1. Display device
2. Real time image generation
3. Head tracking
4. Hand tracking; interaction (<1970)
5. Content



Ultrasonic head position sensor (full position and orientation!)

3 transmitters on head
4 receivers from ceiling

Emergence of VR: 1980s

- A few labs build VR systems "by hand": Wright-Patterson Air Force Lab, U Tokyo, MIT Media Lab, NASA Ames, UNC,..
- Gradually every component become available "off the shelf", made for another market
  - Display device: pocket TVs + wide angle optics (LEEP)
  - Image generation: graphics workstations (Silicon Graphics, ..)
  - Head tracking: Polhemus magnetic trackers (originally for tracking heads-up displays for military jets)
  - Interaction: Polhemus magnetic trackers
- Commercial VR Systems
  - 1987: VPL (Jaron Lanier) ~ $ 100,000 USD
  - Evangelist for "Virtual Reality"
- Early 1990s: VR discovered by popular media

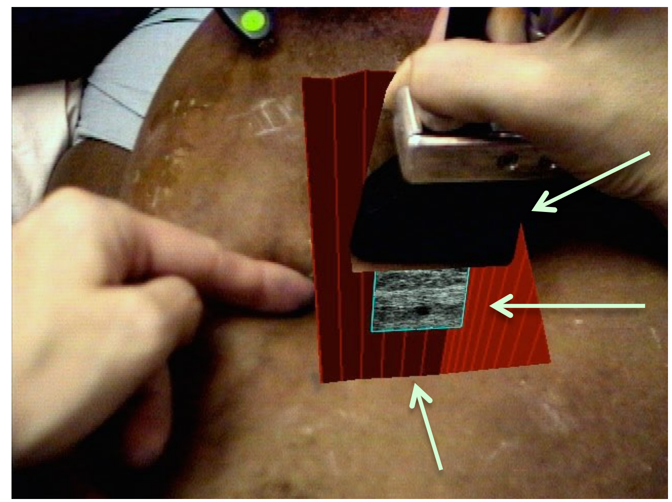
Jaron Lanier ~1987

"I expect that within the next five years more than one in ten people will wear head-mounted computer displays while traveling in buses, trains, and planes"

Nick Negroponte, Founder, MIT Media Lab, 1993, Wired Magazine

Sample Capability from mid-1990s:
Augmented Reality for Ultrasound-Guided Needle Biopsies (UNC)

Image in HMD



Ultrasound transducer

Ultrasound image

Synthetic hole in patient

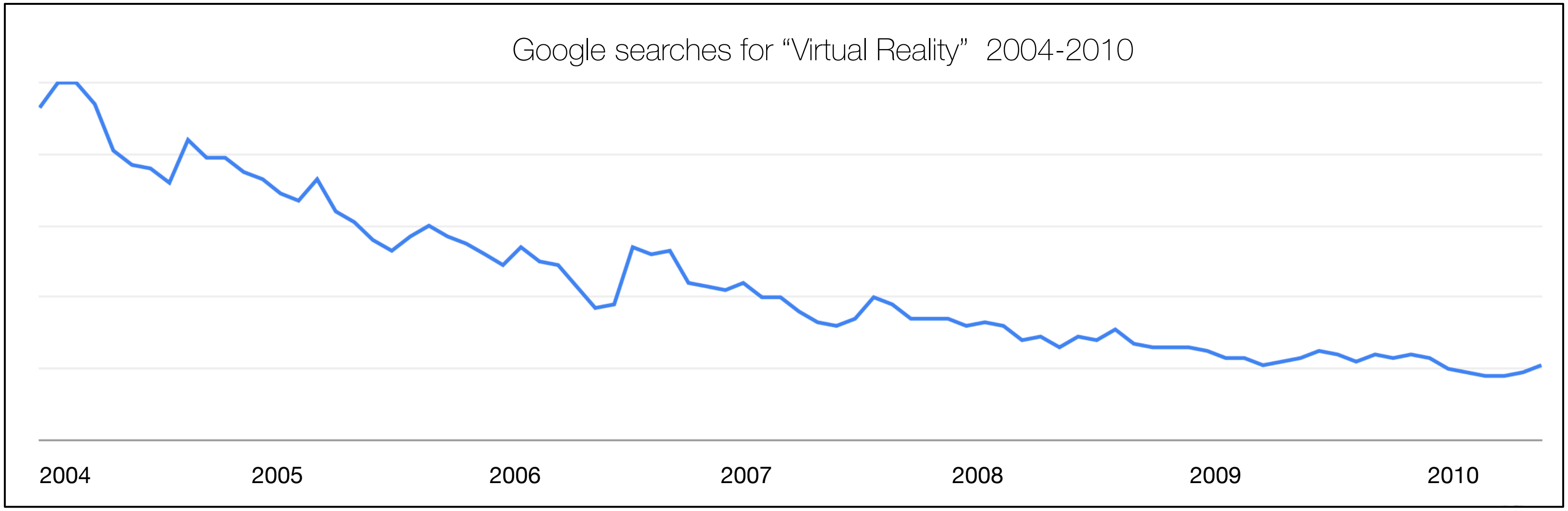
State, A, M Livingston, W Garrett, G Hirota, M Whitton, E Pisano, and H Fuchs, "Technologies for Augmented Reality Systems: Realizing Ultrasound-Guided Needle Biopsies", **SIGGRAPH 1996.**

Why didn't VR Take Off in 2000s ?

1. VR much harder than we thought; technology good enough for only a few small applications, and too expensive for consumers

2. "Whatever Happened to … Virtual Reality?"

   C. Mims, MIT Tech. Review, Oct. 2010



Why Did VR Take Off in 2014 ?

Technology good enough

- Display device: smartphones (iPhone5 Sept. 2012 1136x640)
- Image generation: PC graphics cards & smartphones
- Head tracking: inertial sensors, cameras in smartphones
- Interaction: cheap depth cameras (Kinect,..)

— Facebook purchasing Oculus VR, March 2014: $ 2B !

Pitfalls

1. Technology not good enough for mass adoption
2. Where is the mass market?
   - VR: Gaming, entertainment (movies, sports),..

     -Social VR, Telepresence?

   - AR: "next major computing platform, after mobile"

     Mark Zuckerberg, Facebook CEO

1: Remaining Technology Challenges

VR (gaming, entertainment,..)

- ✸ Wireless headset (here)
- ✸ Room-based tracking (here)
- ✸ Lower price
- Walk in large virtual areas
- See own body: hands, feet,..
- ..

AR (next computing platform?)

- ✸ Self-contained, mobile (HoloLens)
  - Self-tracking; go anywhere
  - Hand-based interaction
  - Convenient text/keyboard
- ✸ Eyeglass form factor
- ✸ Wide field of view
- Low latency: tracking & display (reduce cybersickness)
- Visual comfort: vergence-accommodation conflict

2: Application Challenges: one sample

- ✸ Social VR or Telepresence

✸ Most important

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  — Maimone2014
- Low latency: tracking & display (reduce cybersickness) — Lincoln2016,17
- Visual comfort: vergence-accommodation conflict — Dunn2017

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- ✸ Social VR or Telepresence — Maimone2013 — Dou2014,15,16 — Cha2016

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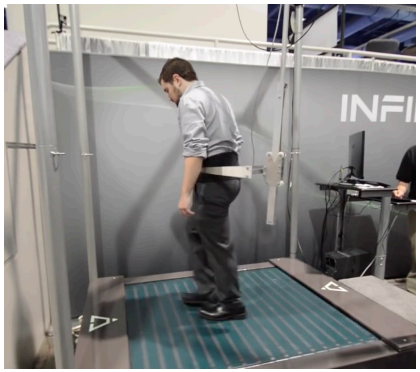
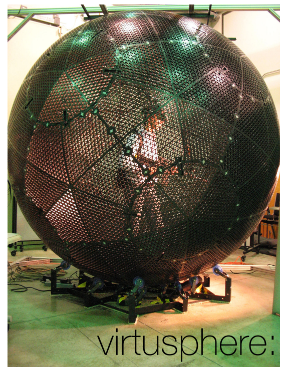
Walking in a Virtual Space Larger than the Physical Space 1 of 3

1. Problem: walk around a virtual house but only have one physical room
2. Other approaches



Infinadeck: omnidirectional treadmill



virtusphere: human-sized hamster ball

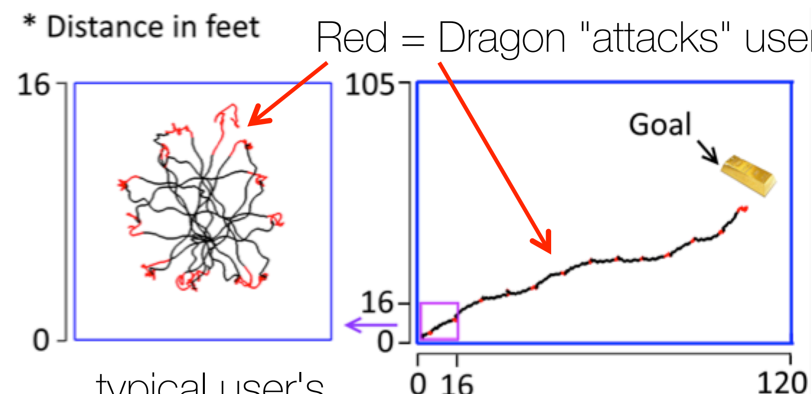
VR house that user walks around in, while physically only in a single small room

3. Our approach: "redirected walking" (Razzaque2001): VR software rotates the virtual scene imperceptibly; user compensates and thereby doesn't walk out of the physical space.
4. System can "rotate" the user more when they rotate their head quickly, so add a distractor (Peck 2010) that's part of the virtual scene that stimulates user to rotate head quickly

Chen, H and H Fuchs "Supporting Free Walking in a Large Virtual Environment: Imperceptible Redirected Walking with an Immersive Distractor," **Comp. Graphics International 2017** Yokohama, June 27-30.

Walking in a Virtual Space Larger than the Physical Space 2 of 3

1. Users think they're walking around a basketball court, playing an immersive game
2. Actually walk only in a 16 x 16 ft. corner of it !
3. Dragon "attacks" user when they get near the edge of the 16 x 16 ft. area.
4. VR software imperceptibly rotates user

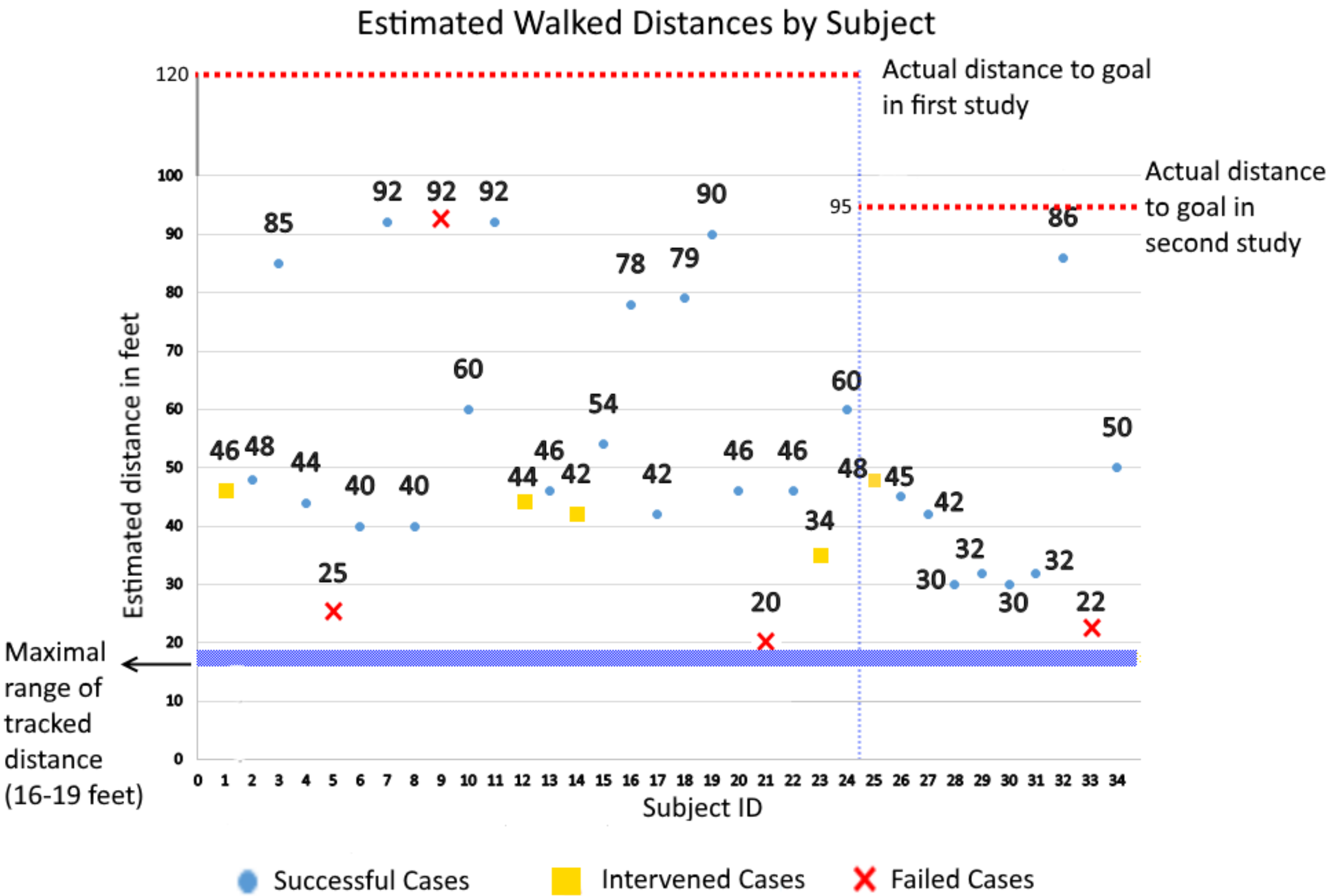


typical user's walking path in physical space

user's path in virtual space

Chen, H and H Fuchs "Supporting Free Walking in a Large Virtual Environment: Imperceptible Redirected Walking with an Immersive Distractor," **Comp. Graphics International 2017** Yokohama June 27-30.

Result: Walked Distance Estimation



Results may transfer to other immersive experiences:

Virtual children and pets distracting a user walking around a virtual model home.

Imperceptible Redirected Walking:
Reactions at end of experience

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2: Application Challenges: one sample

- ✸ Social VR or Telepresence ← Maim ne2013 ← Dou2014,15,16 ← Cha2016

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Pinlight Displays: Basics

1. Place a tiny light source, like LED, close to the eye, few mm farther than eyeglass lenses; will see the light "out of focus", a disk

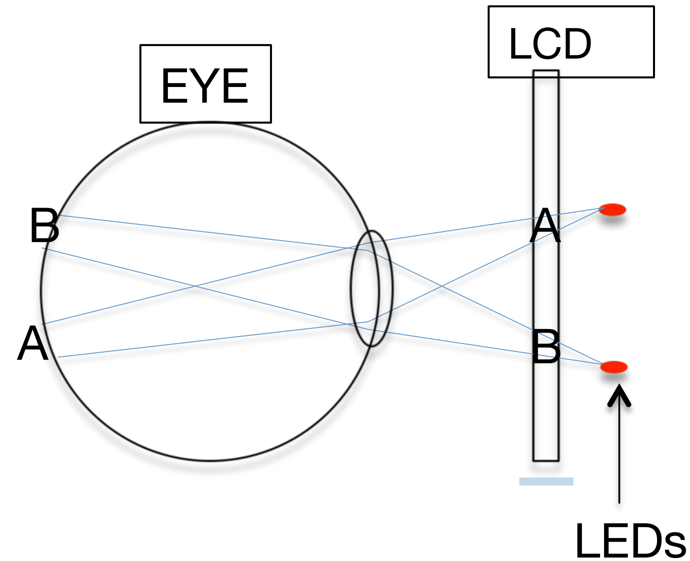
2. Put an LCD (without backlight) between LED and eye; will see a pattern on the 'out of focus' disk of LED

   The pattern (e.g. part of letter A) will be in focus

3. Add another LED 1-2mm next to the first, will get another "out of focus" disk on the retina, patterned by another part of the LCD

4. Make the distance between the 2 LEDs so their disks overlap on the retina, but their areas on the LCD don't overlap

5. Keep adding more and more LEDs until the entire LCD is covered, the most of the retina will be covered



Maimone, Lanman, Rathinavel, Keller, Luebke, Fuchs "Pinlight Displays: Wide Field of View Augmented Reality Eyeglasses Using Defocused Point Light Sources," **SIGGRAPH 2014**

Pinlights Display (Maimone 2014)

Maimone, Lanman, Rathinavel, Keller, Luebke, Fuchs “Pinlight Displays: Wide Field of View Augmented Reality Eyeglasses Using Defocused Point Light Sources,” **SIGGRAPH 2014**

Newer, entirely different design: Maimone, A, A Georgiou, J Kollin, “Holographic Near-Eye Displays for Virtual and Augmented Reality,” **SIGGRAPH 2017**

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Cyber sickness: virtual world “swimming”, jitter

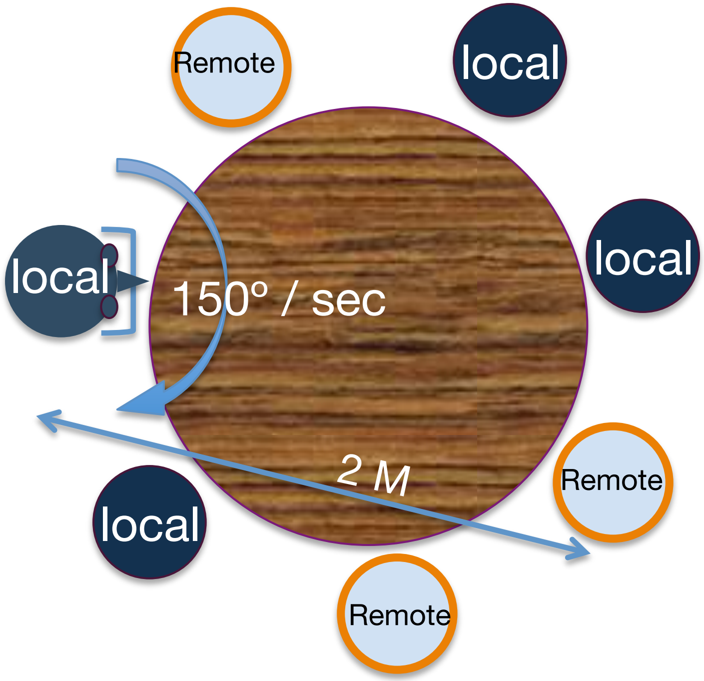
1. Conflict between visual and vestibular cues (semicircular canals in ear that interpret cues from gravity and acceleration)

2. Cause: Lag between head movement (vestibular cues) and virtual image (visual cues)

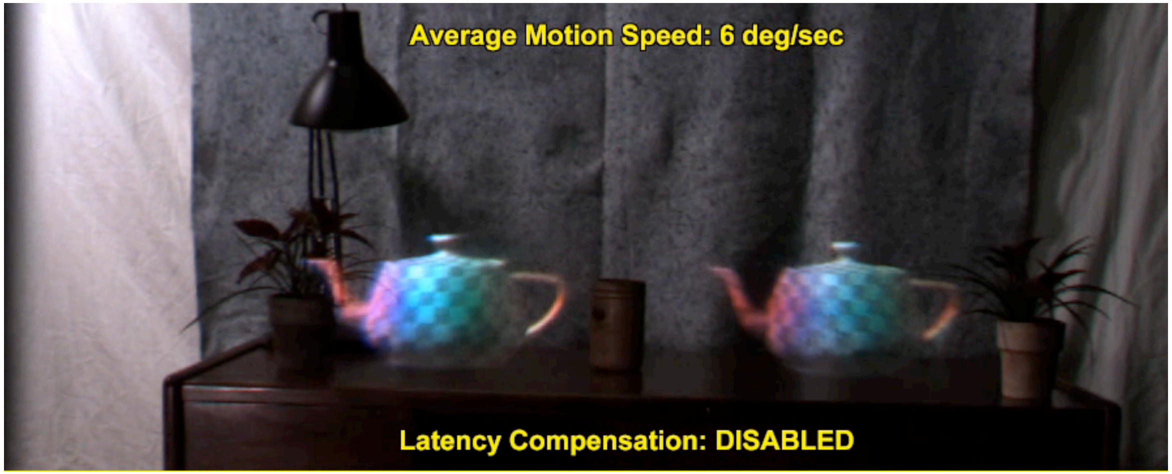
3. Culprit: End-to-end latency: from head motion to photons into the eye
   - Satisfactory 1990-2000: 50-75 millisec
   - Satisfactory 2015: 10-20 millisec
   - May need < 1 millisec for AR

Motivation for Low Latency AR

Viewing local and remote people around a table



total latency	degrees moved	arcmin	error: nm. pixels (60°,HD)	error in mm
10 millisec.	1.5	90	48	52.36
1 millisec.	0.15	9	4.8	5.24
100 microsec.	0.015	0.9	0.48	0.52

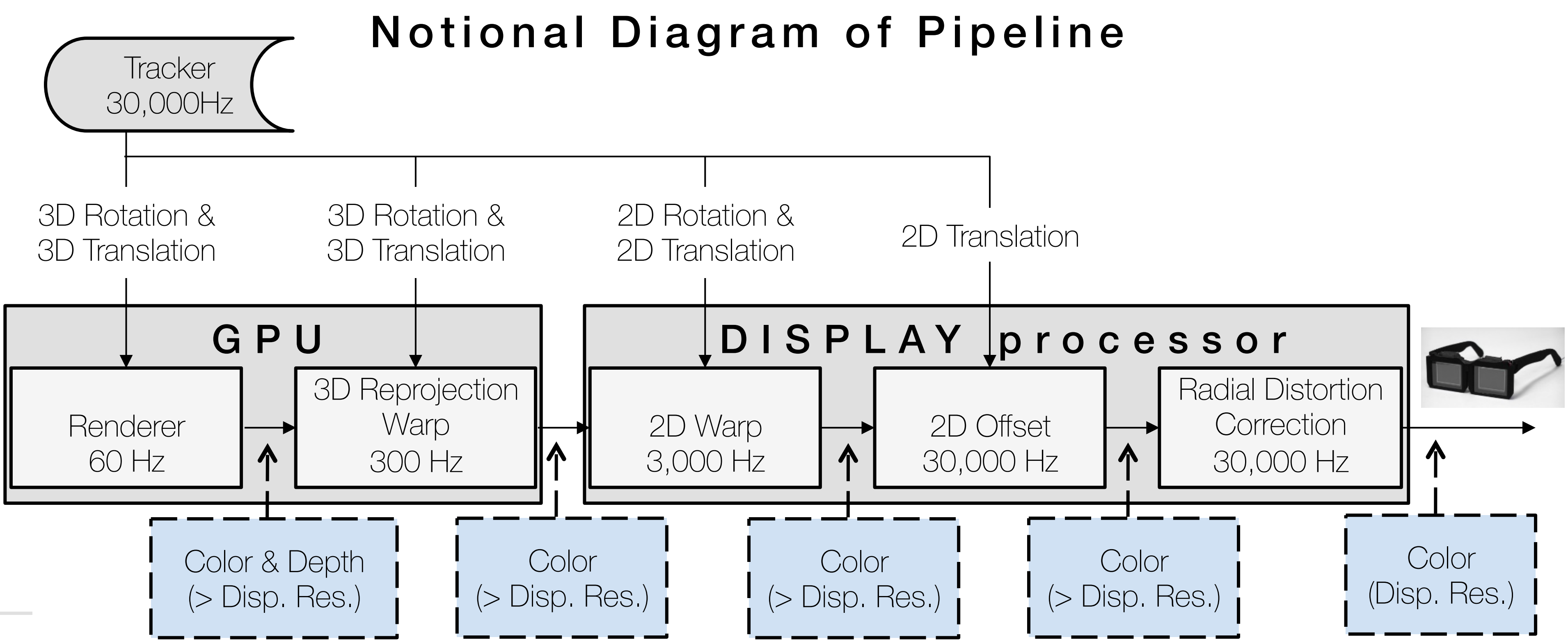


Lincoln, Blate, Singh, Whitted, State, Lastra, Fuchs "From Motion to Photons in 80 microseconds: Towards Minimal Latency for Virtual and Augmented Reality" **IEEE VR 2016**
Best Paper Award

Lincoln, Blate, Singh, State, Whitton, Whitted, Fuchs "Scene-Adaptive High Dynamic Range Display for Low Latency Augmented Reality" **ACM i3D 2017**

Low Latency Render Cascade Pipeline

1. Tracking system reports to PC and all pipeline stages
2. PC/GPU performs conventional AR rendering
3. Display hardware performs series of simple Post-Render Warps (PRW)

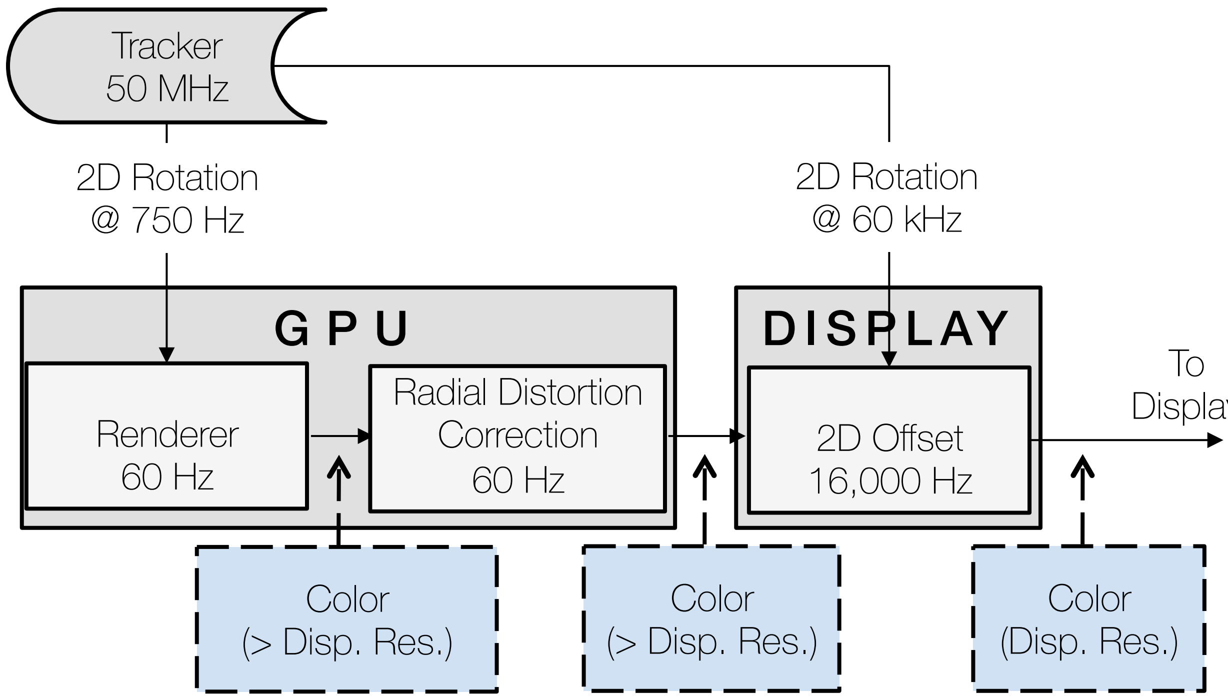


Simplified Low Latency Render Pipeline

1. Conventional AR rendering and radial distortion correction in GPU
2. 2D image translation in display hardware (FPGAs)

Optically See Through AR “HMD”

Implemented Pipeline



Low Latency Display

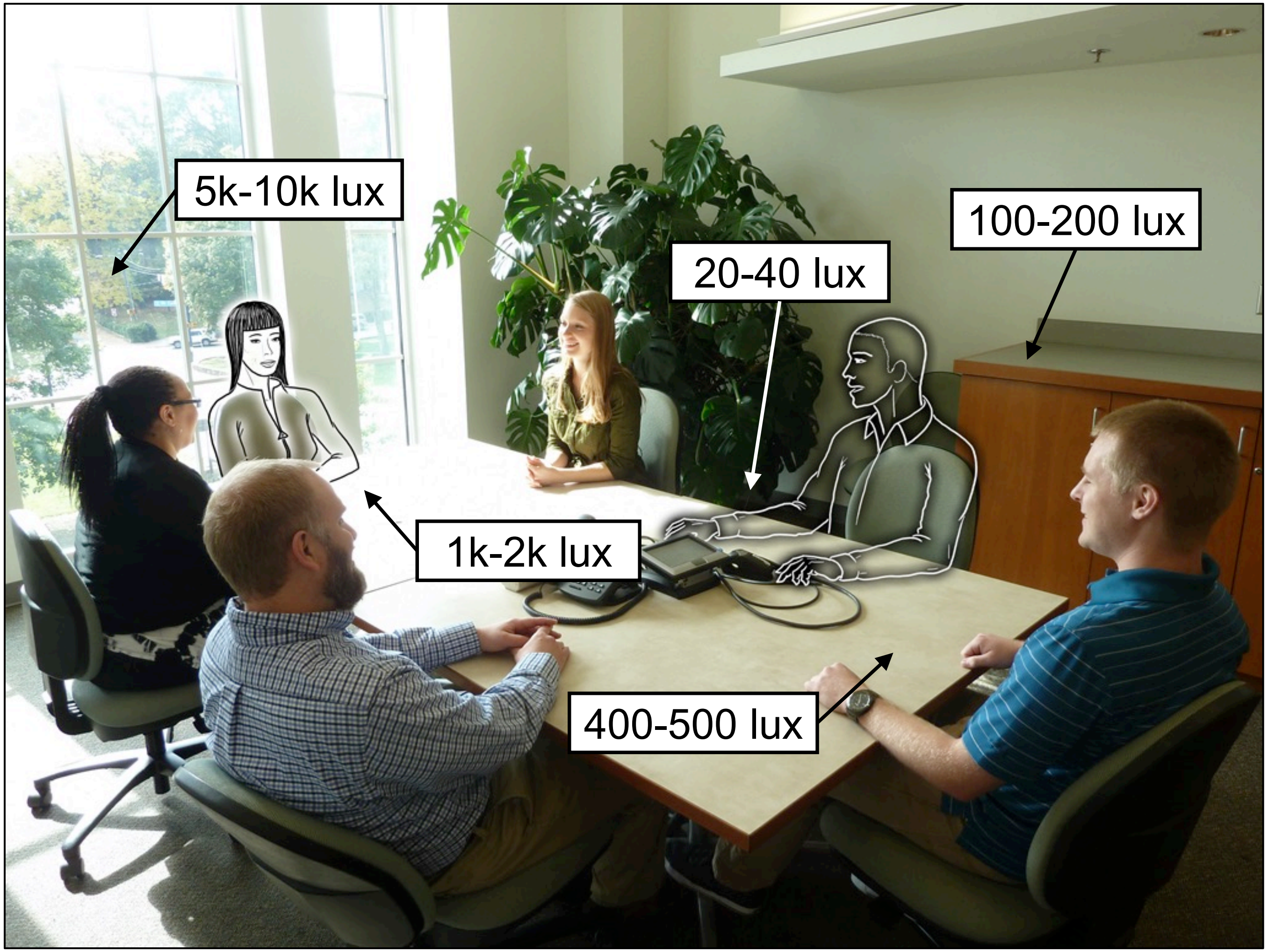
- Uses Digital Micromirror Display (DMD) and FPGAs
- ~120 microsec Motion-to-Photon latency

through the AR HMD

OLD

NEW

Need for High Dynamic Range AR Display



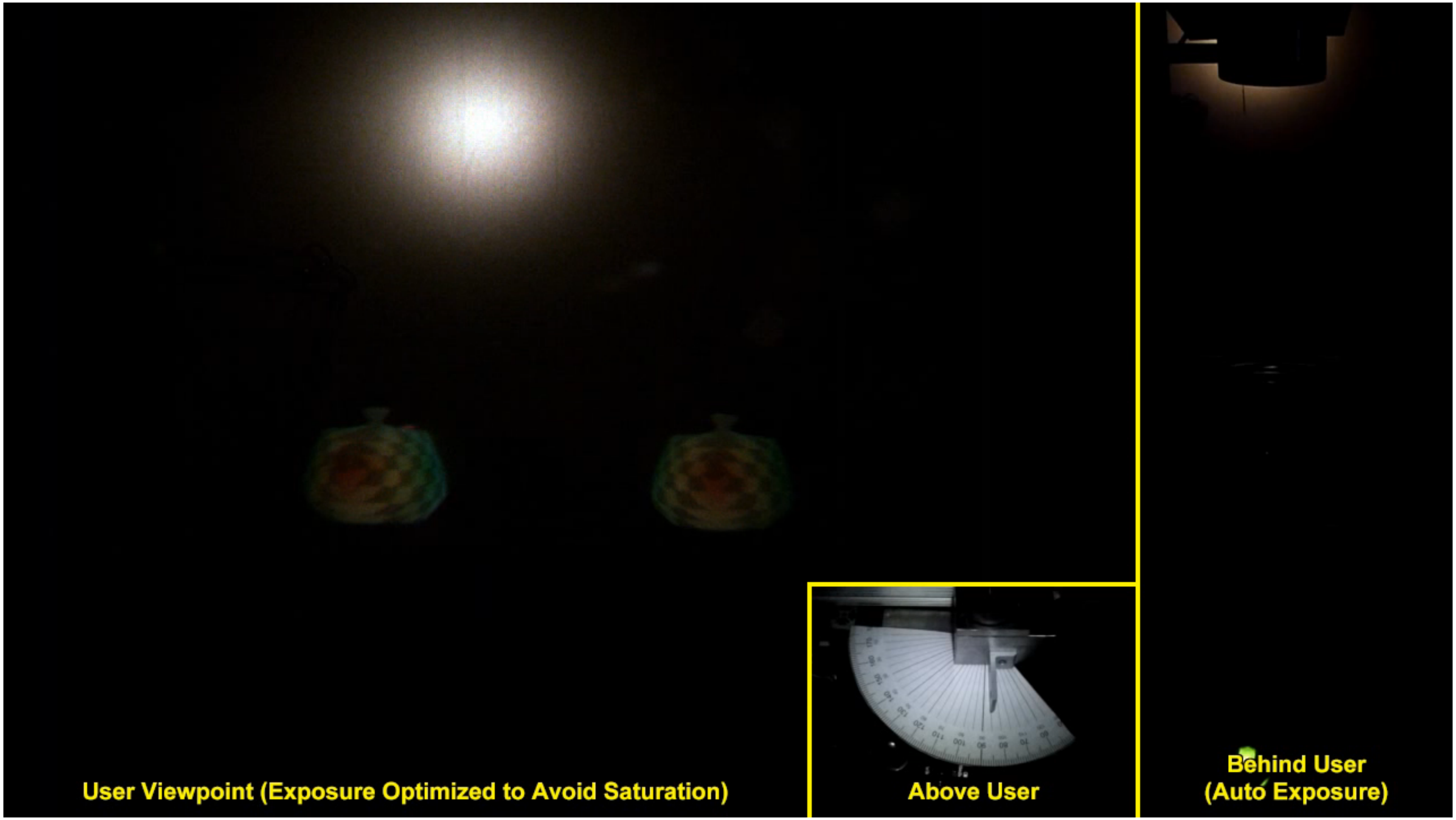
High Dynamic Range HMD & Scene

Low Latency and High Dynamic Range Display (16 bits/color)

Showing HDR display, captured with a low dynamic range camera &low dynamic range display

Lincoln, Blate, Singh, State, Whitton, Whitted, Fuchs "Scene-Adaptive High Dynamic Range Display for Low Latency Augmented Reality" **ACM i3D 2017** **Award: 2nd Best Paper**

Low Latency and High Dynamic Range Display and Adaptation to Local Real Scene Brightness



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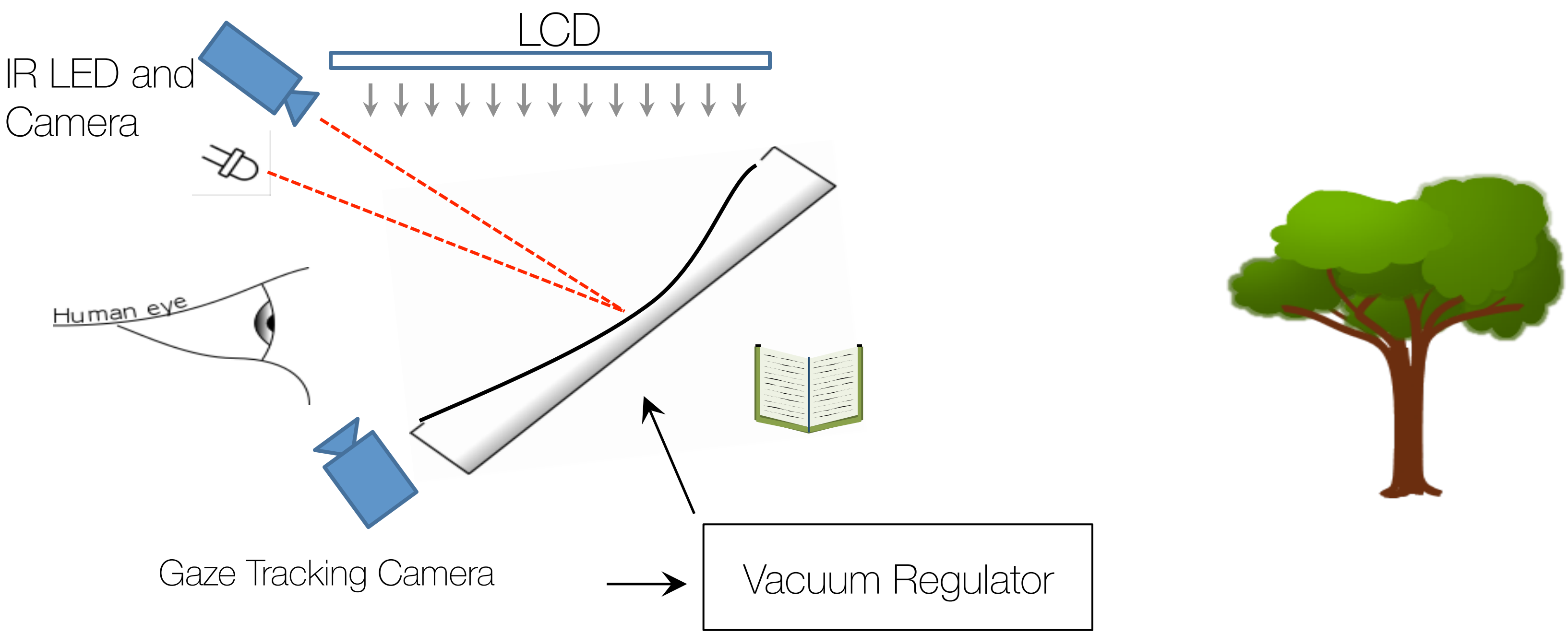
2: Application Challenges: one sample

- ✸ Social VR or Telepresence — Maimone2013, Dou2014,15,16, Cha2016

✸ Most important

Reducing Vergence-Accommodation Conflict

1. Adjust focal distance of internal display to match distance of user's current point of attention
2. Especially important in AR



Dunn, Tippets, Torell, Kellnhofer, Aksit, Didyk, Myszkowski, Luebke, Fuchs "Wide Field Of View Varifocal Near-Eye Display Using See-Through Deformable Membrane Mirrors." **IEEE VR 2017** **Best Paper Award**

Wide FOV Near-Eye AR Display

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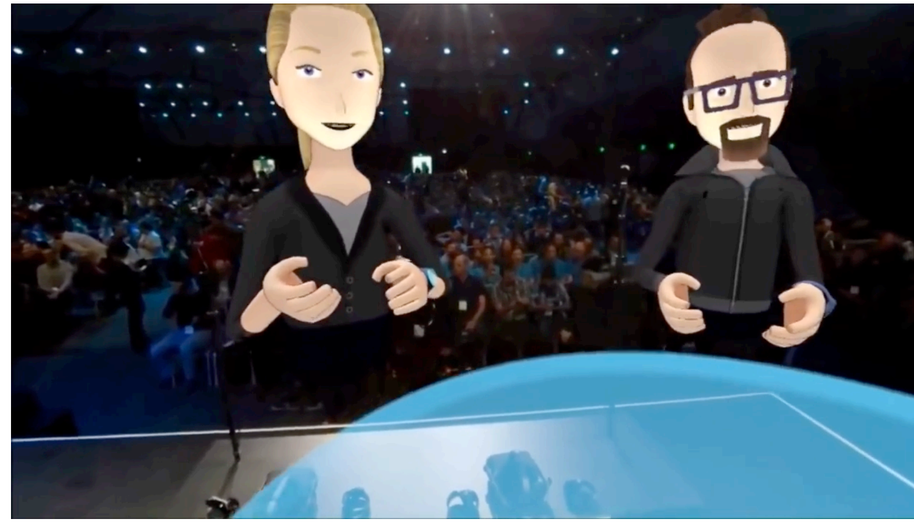
A Potential Major Use of VR/AR: TELEPRESENCE

Video Teleconferencing

Cisco TelePresence 3000

Social VR

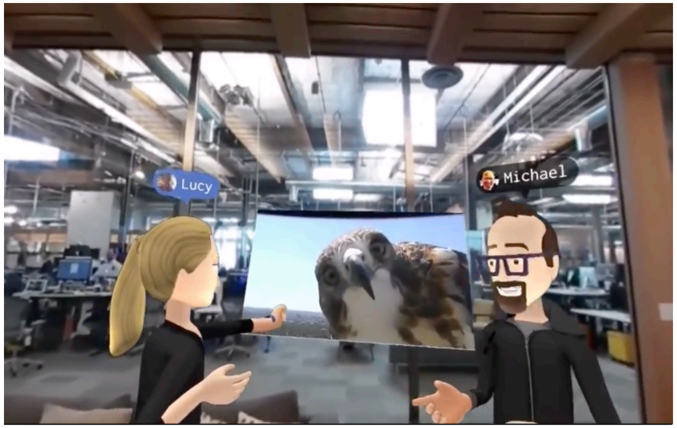


Facebook/Oculus Social VR Demo, Oct.2016

Issues

1. Display h/w
   - Fixed, conventional
   - Head gear (AR, VR)
2. Images of participants
   - Video
   - Cartoon avatars
     -how control expressions?
   - 3D scans & 3D reconstruction
3. Images of environments
   - 2D video
   - Spherical videos
   - 3D reconstructions

Cisco TelePresence 3000



Facebook/Oculus Social VR Demo, Oct.2016, "Spaces"

Display Alternatives

Fixed: 2D, stereo, autostereo, multiscopic

- Pro: Nothing to wear on the face (sometimes, shutter glasses)
- Pro: Multiscopic: good eye contact
- Con: local & remote participants can't be in same shared space
- Con: Multiscopic extremely expensive

Head worn:

- VR: Pro: cheap, immersive
- VR: Con: cannot see own body, local people and space
- AR: Pro: see own body and local environment
- AR: Con: wide field of view just out of reach, clunky
- AR: Con: virtual objects (distant people) cannot occlude real world, either appear transparent or real world has to be dark

Holografika

Oculus

Microsoft Hololens

Next AR Demo shows 2 different things

1. Why it would be useful to have virtual objects in an AR headset appear <u>solid</u> rather than just <u>transparent</u>
2. If both the participant and their environment is continuously 3D scanned in real-time, result is a strong sense of shared presence

AR: Poor integration of real & virtual objects

1. Lack of proper occlusion between real and virtual objects
2. Difficult to see both virtual and real objects simultaneously
   - Usually real background is dimmed
3. Occlusion of virtual object (person) is easy: lower part of remote person behind the table is removed
   - Assume both the local scene and remote person are real-time 3D scanned
4. Occlusion of real object (wall) by virtual object (person) is hard

Old: remote person is transparent

Occlusion of real object (wall) by virtual object (person)

Solutions:

A) Add occlusion mask of real world in the headset: Hard [Kiyokawa 2003]… (not yet done for wide field of view)

1. Optically project real world to focus onto the occlusion mask (a spatial light modulator, LCD)
2. Combine the portion of the image that gets through the occlusion mask with the virtual image

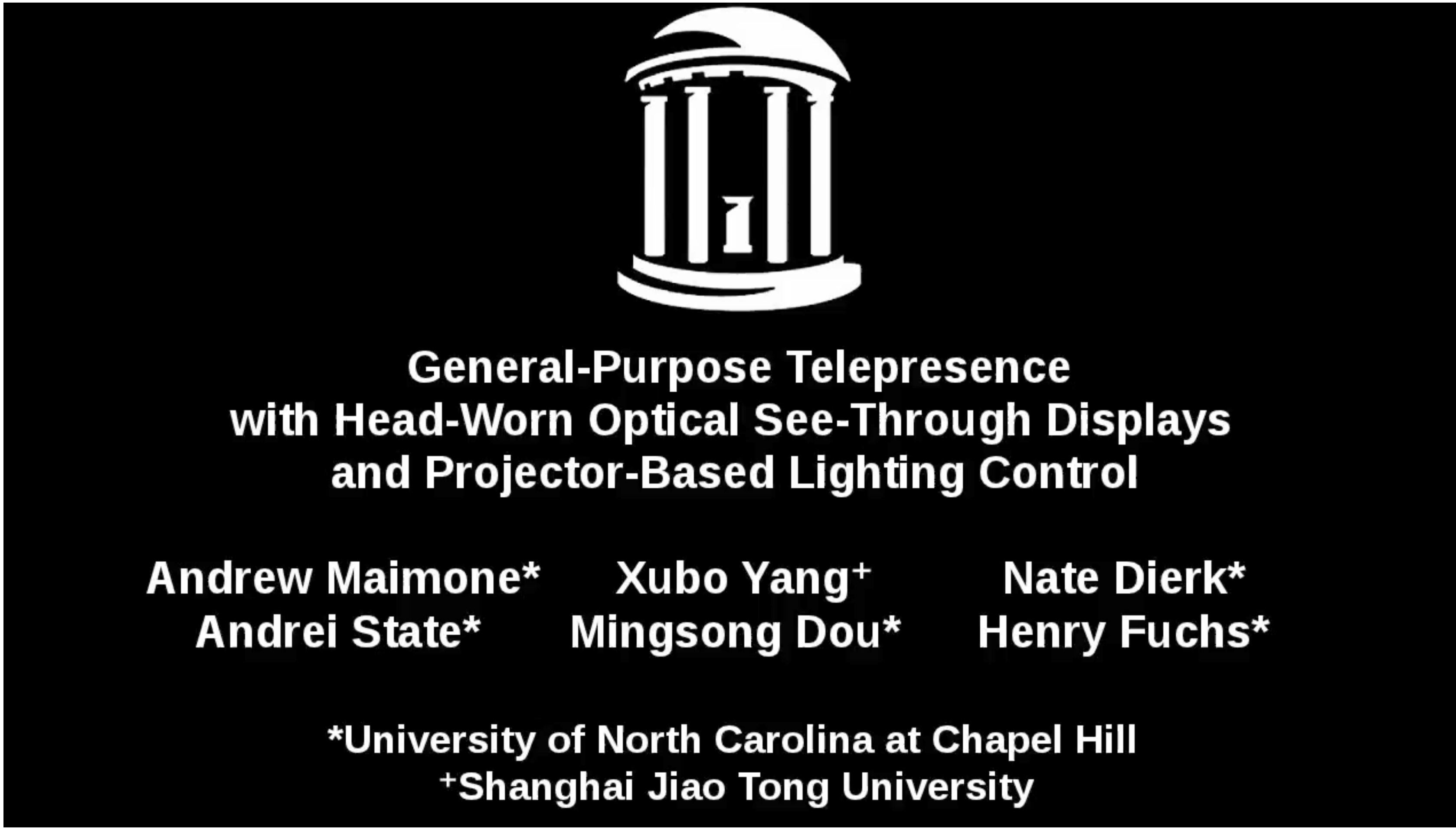
B) Our new demo of wide angle solution for single user: (mono)

1. Replace local room lights with projectors
2. Acquire real-time 3D of local & remote scenes
3. Turn a projector pixel black if it is going to light up a local surface that should be occluded

Old: remote person is transparent

New: remote person is solid

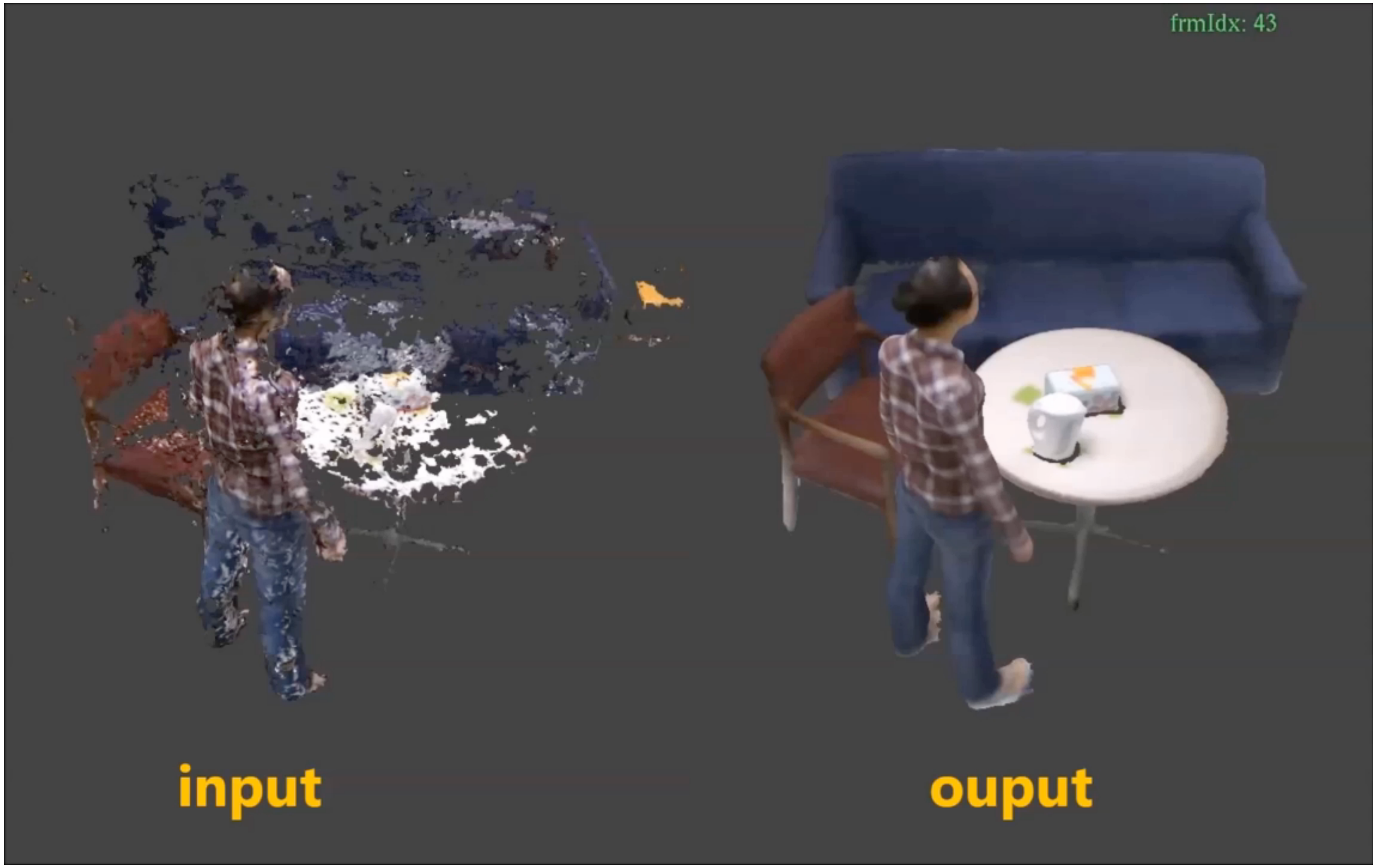
Telepresence with Solid-Looking Remote People



Maimone, A, X Yang, N Dierk, A State, M Dou, and H Fuchs, General-Purpose Telepresence with Head-Worn Optical See-Through Displays and Projector-Based Lighting, IEEE Virtual Reality 2013. Best Short Paper Award

Improving Scene Capture (2014)

1. Multiple (10) Kinect color+depth cameras
2. Time-based integration of dynamic surfaces



Dou, M and H Fuchs "Temporally Enhanced 3D Capture of Room-sized Dynamic Scene with Commodity Depth Cameras" **IEEE VR 2014** Best Short Paper

Scene Acquisition (2015)

1. Single Kinect color+depth camera
2. Time-based integration of deformable surfaces

IEEE Conference on Computer Vision and Pattern Recognition 2015

3D Scanning Deformable Objects with a Single RGBD Sensor

Mingsong Dou[1] Jonathan Taylor[2] Henry Fuchs[1] Andrew Fitzgibbon[2] Shahram Izadi[2]

[1]Department of Computer Science, UNC-Chapel Hill

[2]Microsoft Research

Dou, M., J. Taylor, H. Fuchs, A. Fitzgibbon, S. Izadi. "3D Scanning Deformable Objects with a Single RGBD Sensor." **CVPR 2015**

Scene Acquisition, Microsoft Research (2016)

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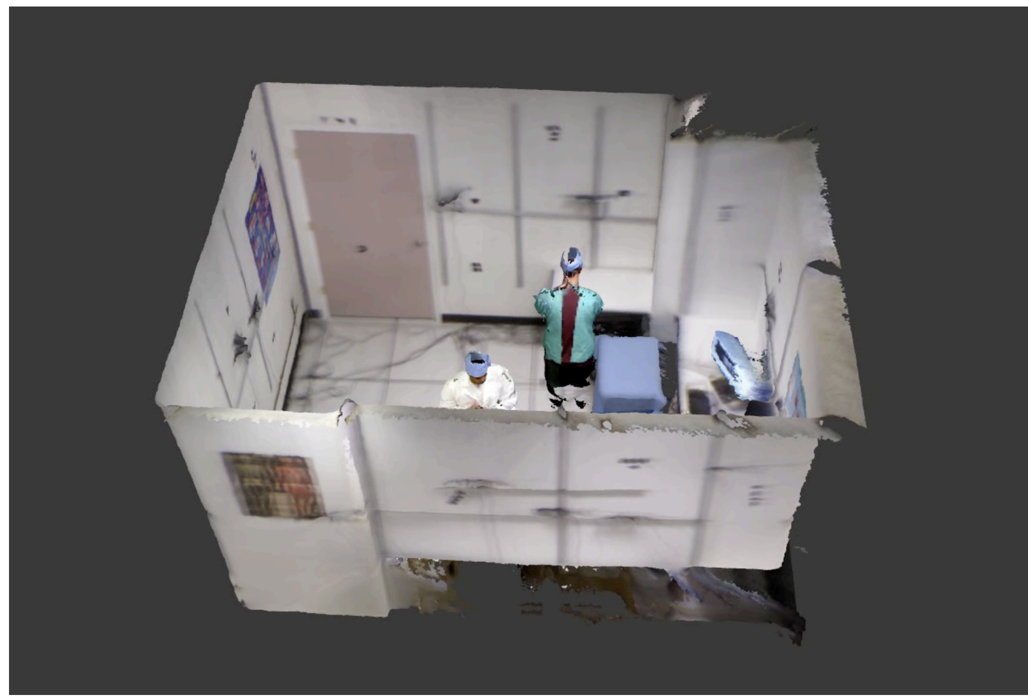
Fusion4D: Real-time Performance Capture of Challenging Scenes Mingsong Dou, Sameh Khamis, Yury Degtyarev, Philip Davidson, Sean Fanello, Adarsh Kowdle, Sergio Orts Escolano, Christoph Rhemann, David Kim, Jonathan Taylor, Pushmeet Kohli, Vladimir Tankovich, Shahram Izadi (**SIGGRAPH 2016**)

AR Headset Development Still Needed

1. Need larger field of view (Hololens is <40°)
2. Occlusion (so real world doesn't have to be dimmed to see the virtual image)

Recording Mock and Real Surgeries (Prostate Biopsies)



Cha, Dou, Chabra, Menozzi, State, Wallen, Fuchs, "Immersive Learning Experiences for Surgical Procedures" **22nd Medicine Meets Virtual Reality / NextMed,** 2016.

Scene Acquisition: Remaining Challenges

1. Entire rooms (furniture, walls) still very difficult – occlusion
2. Much expensive equipment still necessary
3. Mobile acquisition still beyond State of the Art

Conclusions: Promise & Pittfalls of AR/VR

1. Promise: VR "will revolutionize the way we experience movies, news, sporting events, video games, and more" NYTimes 11/19/2015
2. Pittfall: promises won't be realized
   (like ~1940s predictions of "A Helicopter in Every Garage")
3. Technology not ready for mass adoption
   - Headsets too bulky, systems too expensive, no compelling uses, ...
4. Social VR / telepresence: VR environment not compelling
   (people turn off cameras in Skype; choose texting over phone calls,..)
5. Will VR fade in 2020 like it did in 2000s ? Not as likely to fade now ...
6. $ Billions enable technology to be driven by VR needs: displays, sensors,.. not just dependent on tech developed for other markets
7. 2017-2019 crucial for a breakthrough application or system or some companies will leave the market
8. Facebook's Mark Zuckerberg: like Steve Jobs, long-term commitment to a vision combined with leading a powerful company that can make the vision a reality
9. **STAY TUNED – we are living historic times !**

Thank you. Questions?