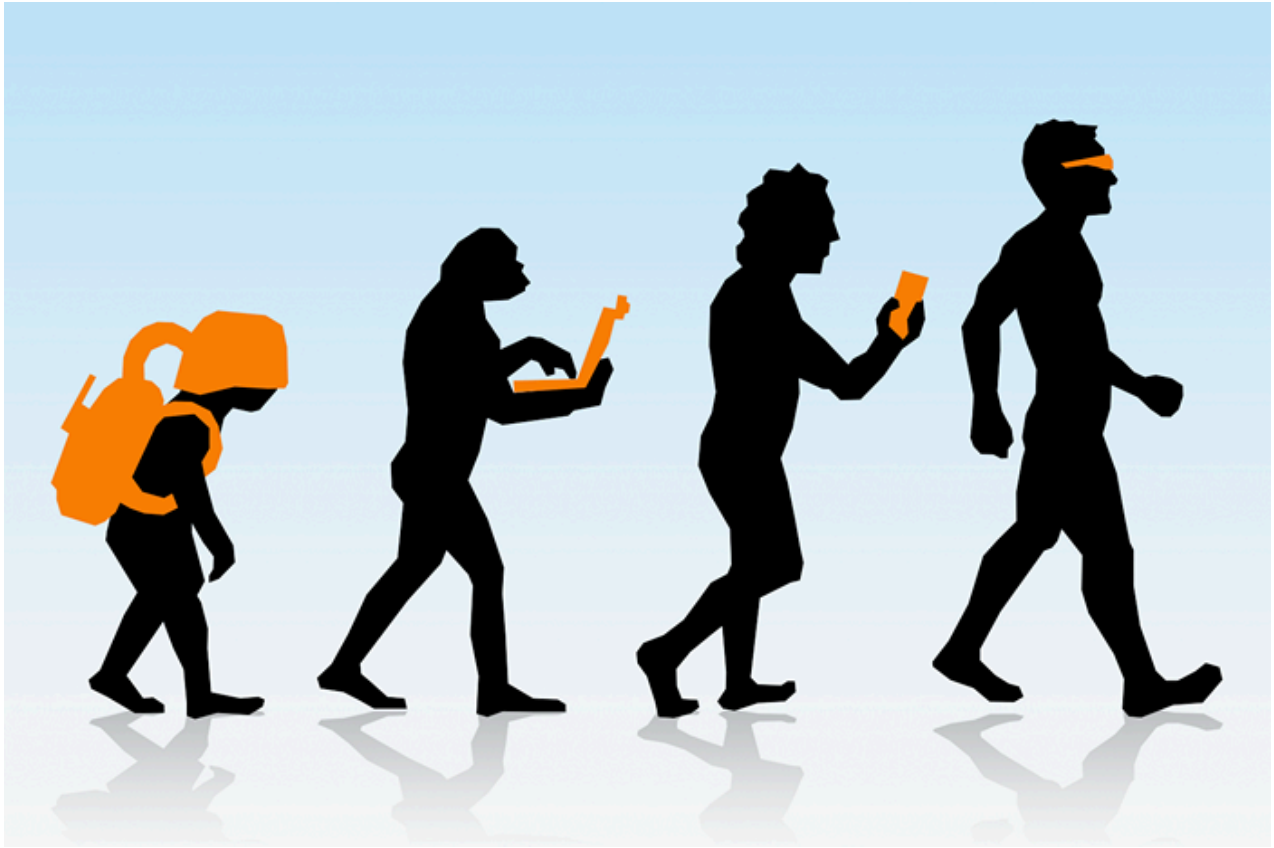
Computer Graphics in VR and AR



ISTD 50.017

Sai-Kit Yeung

Some slides are from Craig Yu

Oculus VR

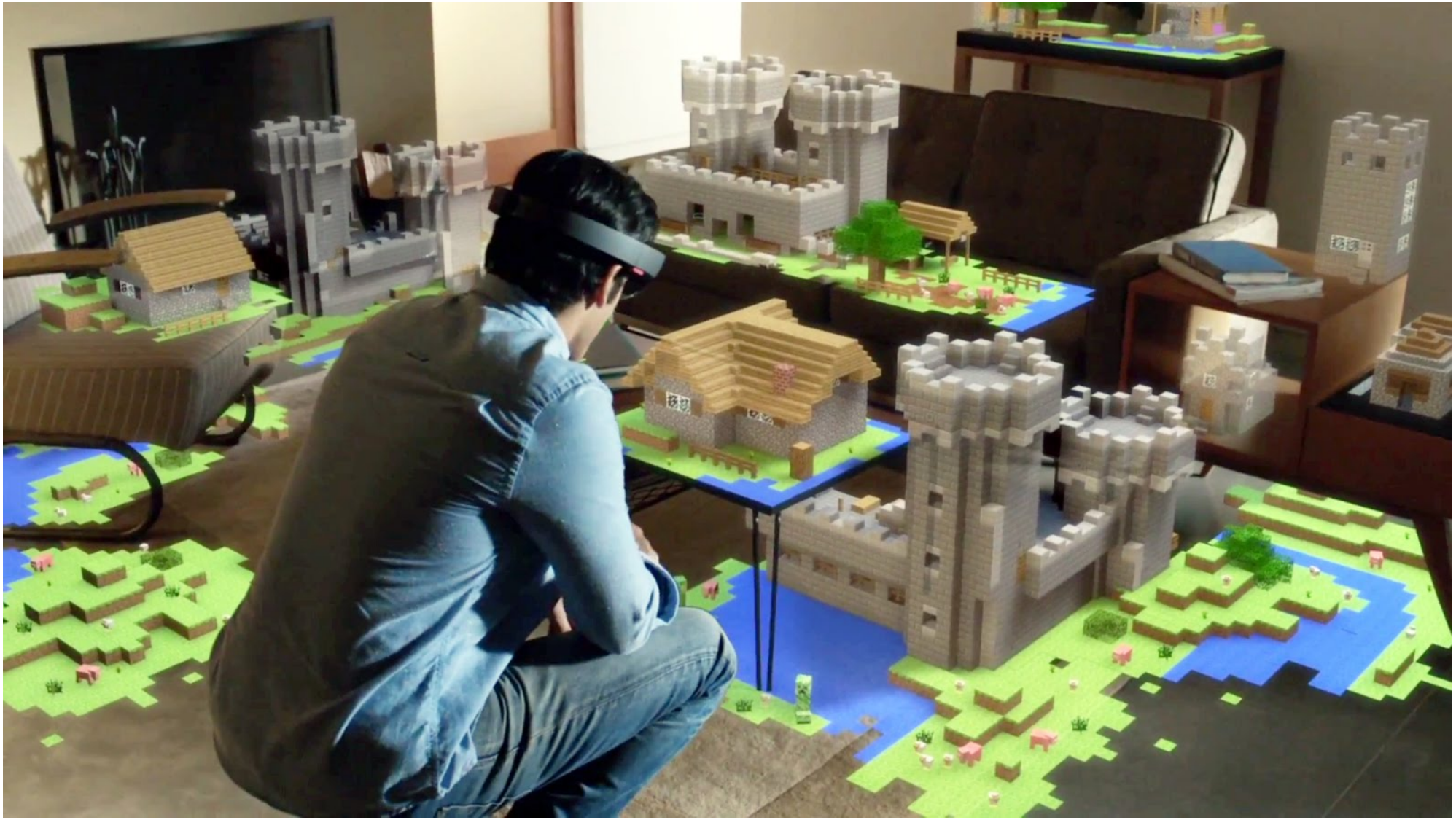
HTC Vive

Playstation VR

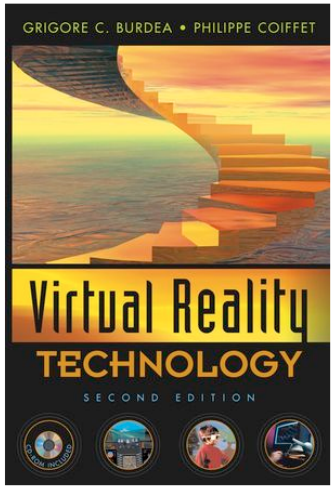
Virtuix Omni Treadmill

Cyberith Virtualizer

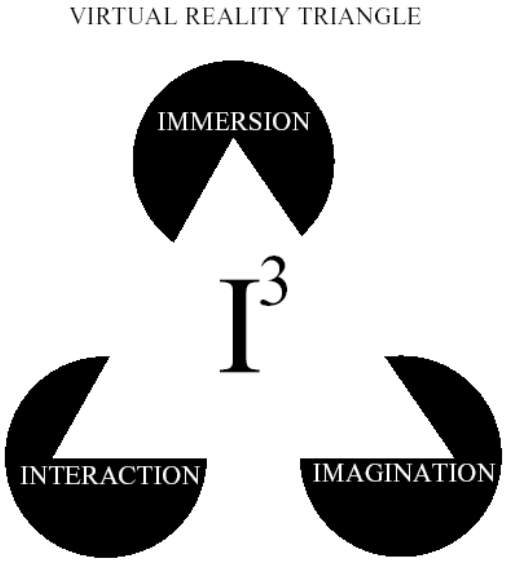
Microsoft Hololens



Define VR



- Grigore C. Burdea, Rutgers:
  - Virtual reality is a high-end user-computer interface that involves real-time simulation and interactions through multiple sensorial channels. These sensorial modalities are visual, auditory, tactile, smell, and taste.
- Burdea's 3 I's for VR:
  - Interactivity – user impacts world
    - Channels
  - Immersion – believing you are there
    - What contributes to it?
  - Imagination – user 'buying' into the experience
    - Why is this necessary?

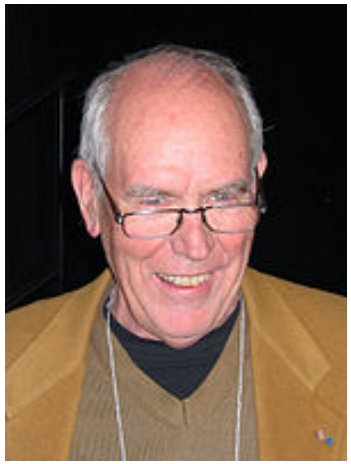


Ivan Sutherland's
The Ultimate Display (1960's)

"Don't think of that thing as a screen, think of it as a window, a window through which one looks into a virtual world. The challenge to computer graphics is to make that virtual world look real, sound real, move and respond to interaction in real time, and even feel real."

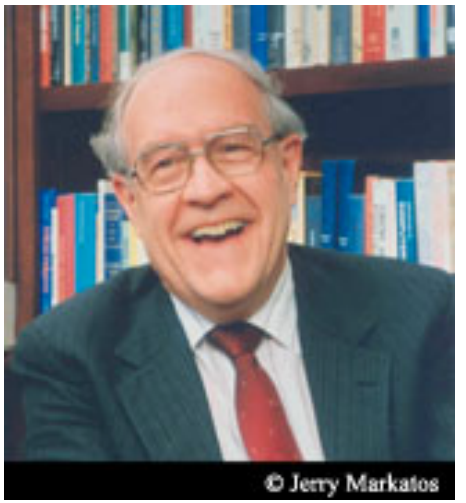
Ivan Sutherland

- Turing Award Winner, 1988
- "father of computer graphics"



Our Definition (from Frederick Brooks' What's Real About Virtual Reality)

- Virtual Reality Experience
  - the user is effectively immersed in a responsive virtual world.
  - Implies -> user dynamic control of viewpoint



Turing Award Winner, 1999

- Control becomes an important element of VR systems.
  - Differentiates VR from books and movies (or watching movies in HMD)
  - Why is control important?

Special Report

What's Real About Virtual Reality?

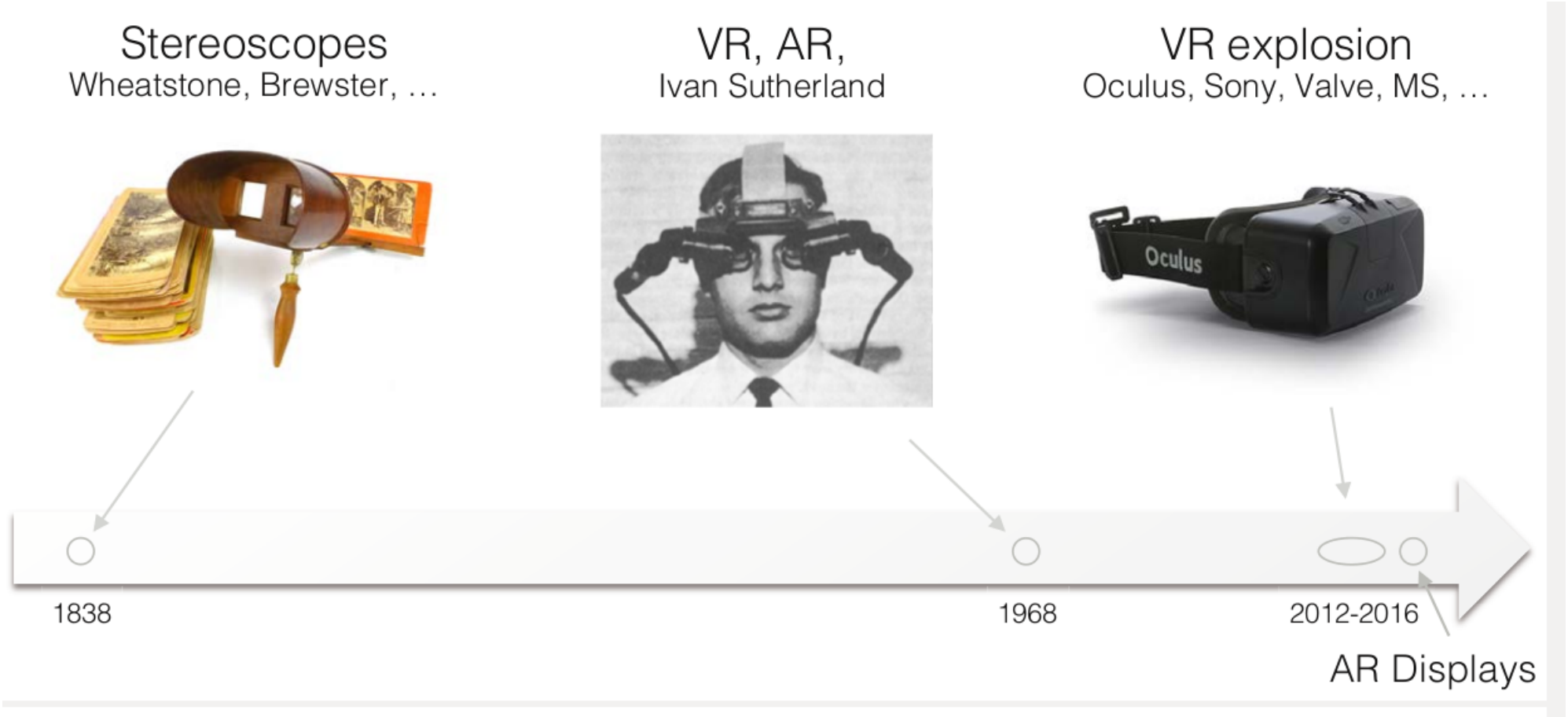
Frederick P. Brooks, Jr.
University of North Carolina at Chapel Hill

As usual with infant technologies, realizing the early dreams for virtual reality (VR) and harnessing it to real work has taken longer than the initial wild hype predicted. Now, finally, it's happening.

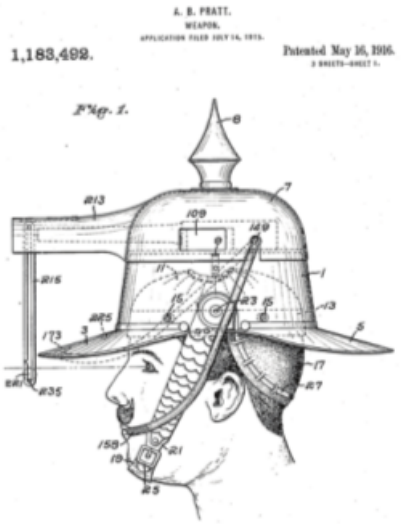
In his great invited lecture in 1965, "The Ultimate Display," Ivan Sutherland laid out a vision[1] (see the sidebar), which I paraphrase:

Europe. Every one of the component technologies has made big strides. Moreover, I found that there now exist some VR applications routinely operated for the results they produce. As best I can determine, there were more than 10 and fewer than 100 such installations as of March 1999; this count again excludes vehicle simulators and entertainment applications. I think our technology has crossed over the pass—VR that used to *almost* work now *barely* works. VR is now really real.

A Brief History of Virtual Reality



A Brief History of Virtual Reality



"HMD"

Nintendo Virtual Boy

VR explosion

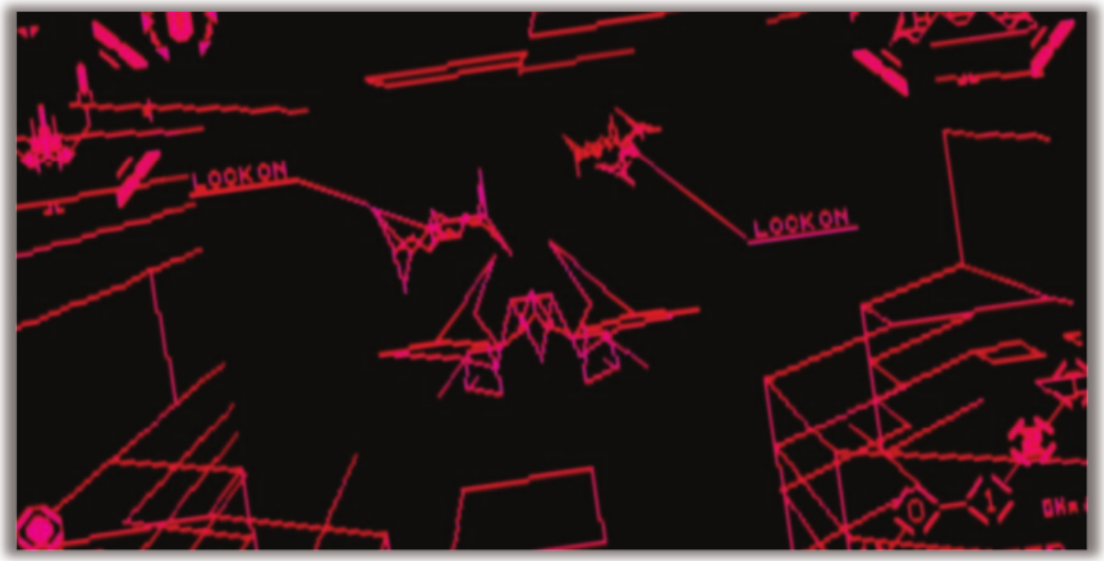
Oculus, Sony, Valve, MS, …

1838 1916 1968 1995 2012-2016

AR Displays

Nintendo Virtual Boy

- 770,000 units sold, commercial failure – judge for yourself



Game: Red Alarm

Key Elements of Virtual Reality Experience

- Virtual World - content of a given medium
  - screen play, script, etc.
  - actors performing the play allows us to experience the virtual world

- Immersion – sensation of being in an environment
  - mental immersion – suspension of disbelief
  - physical immersion – bodily entering the medium
  - Related to **presence** – (mentally immersed) the participant's sensation of being in the virtual environment (Slater)

Walking Experiment at UNC – Chapel Hill

Key Elements of Virtual Reality Experience

- Sensory Feedback – information about the virtual world is presented to the participant's senses
  - Visual (most common)
  - Audio
  - Touch
- Interactivity – the virtual world responds to the user's actions.
  - Computer makes this possible
  - Real-time

Walking Experiment at UNC – Chapel Hill

Other Definitions

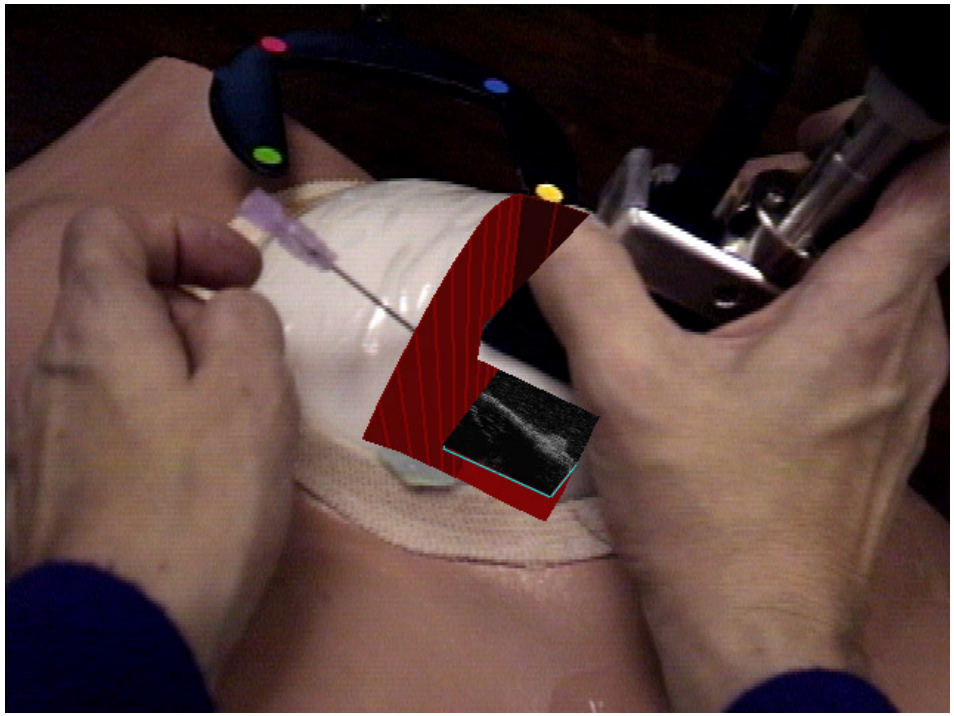
- **Artificial Reality** – synthetic environments in which a user may interactively participate
- **Virtual** – not real. representations of physical objects.
- **Virtual World, Virtual Reality, Virtual Environments** – used interchangeably.
  - Brooks – we aren't even close to creating realities yet.
- **Cyberspace** – location that exists only in the mind of the participants.

Virtual Environments

- Augmented Reality (Mixed Reality)
- Telepresence
- Artificial Reality
- Classical Simulation Environments
- **Virtual Reality**

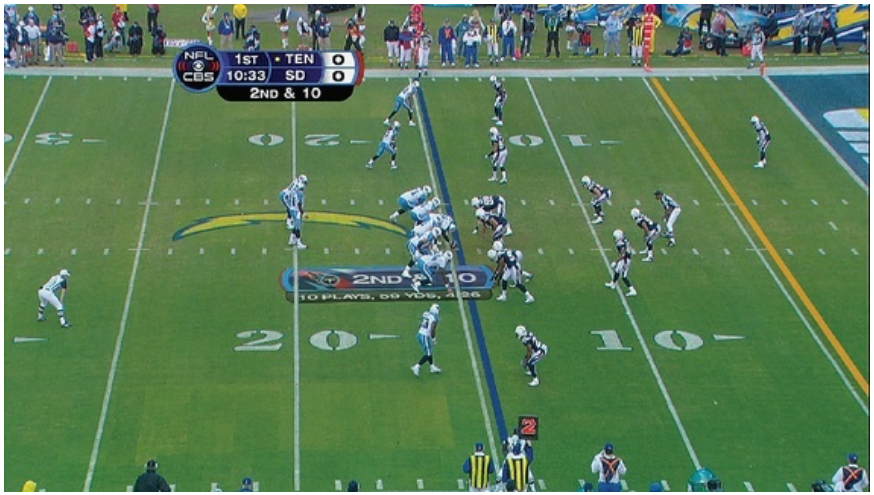
Augmented Reality

- A combination of a real scene viewed by a user and a virtual scene generated by a computer that augments the scene with additional information.



Ultrasound Visualization Research at UNC – Chapel Hill

Augmented Reality: Other Examples



Telepresence

- The use of various technologies to produce the effect of placing the user in another location.

Artificial Reality (Myron Kruger)

Responsive Environment

- Is an environment where human behavior is perceived by a computer which interprets what it observes and responds through intelligent visual and auditory displays

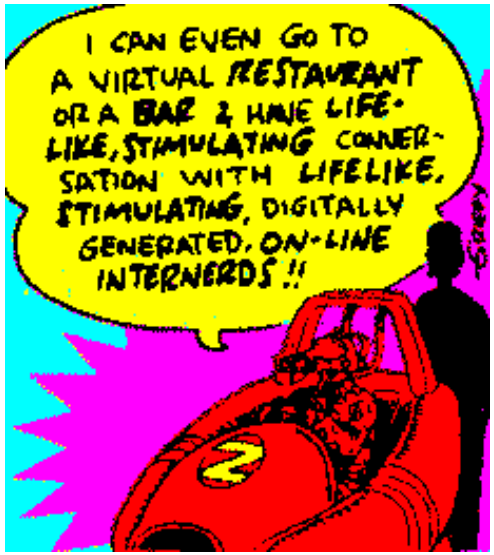
Classical Simulation

- Classical simulation is a mix of real objects and computer generated stimuli.

Virtual Iraq, USC, ICT US Department of Defense

Virtual Reality

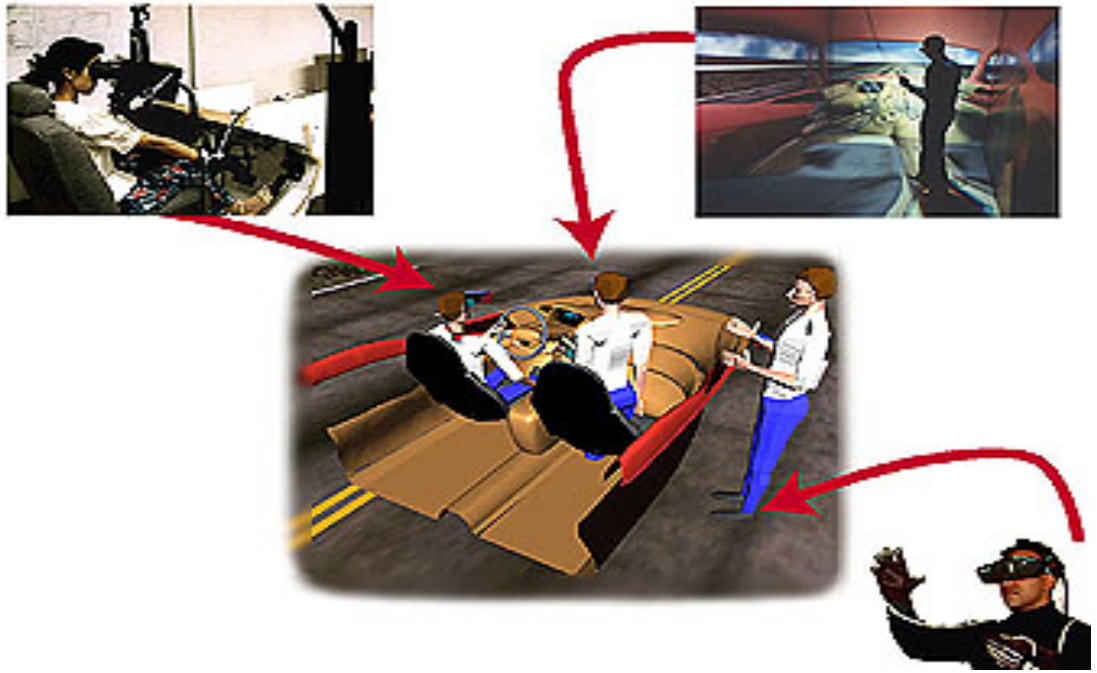
- Ideal for VR is that everything you experience is computer-generated.



VR usually implies

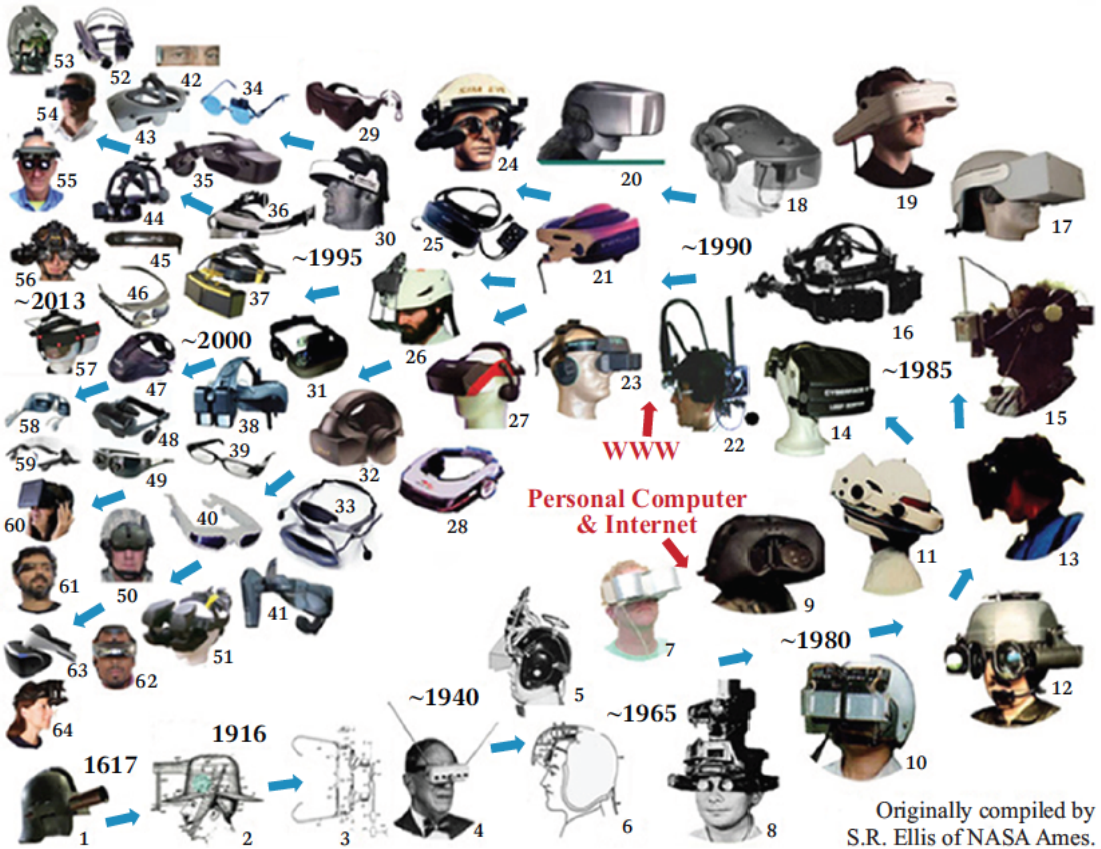
- Immersive Technology
- Real-time first person view
- Environment responds to you (at least at the level of head-motion)

- Distributed VR:



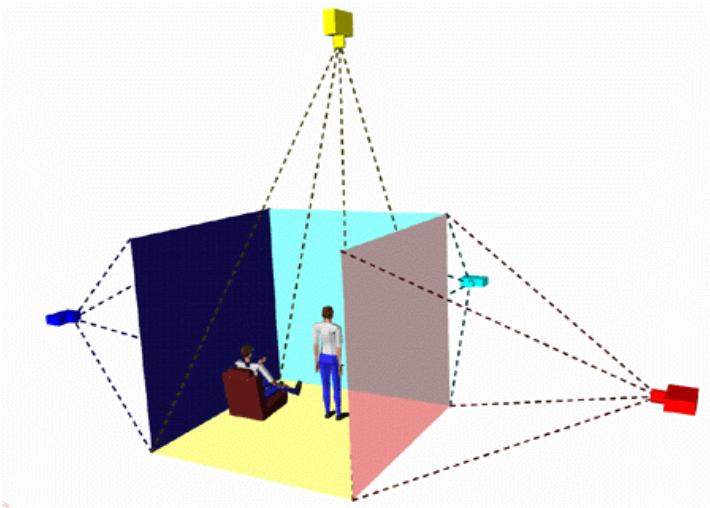
Immersive Technology

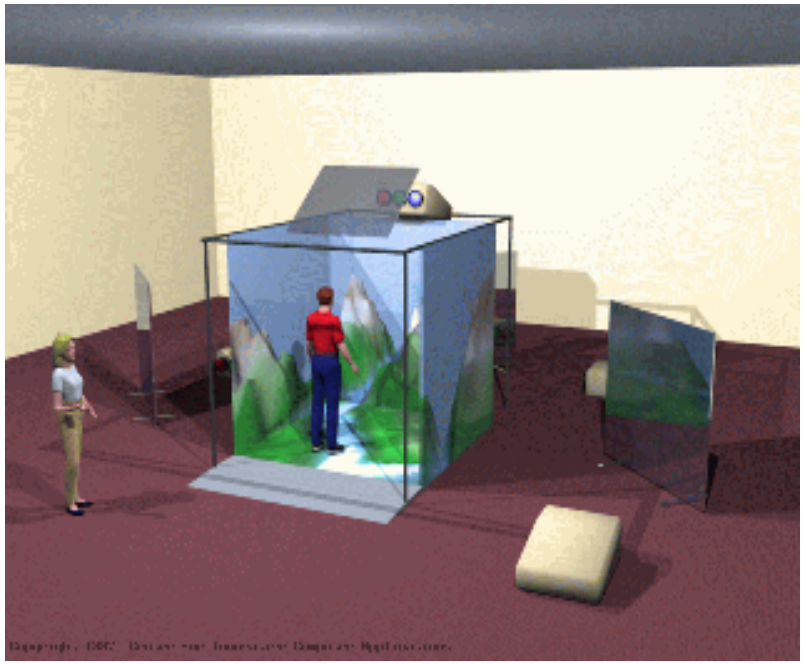
- Head-mounted Display
  - Optical System
  - Image Source (CRT or LCD)
  - Mounting Apparatus
  - Earphones
  - Position Tracker



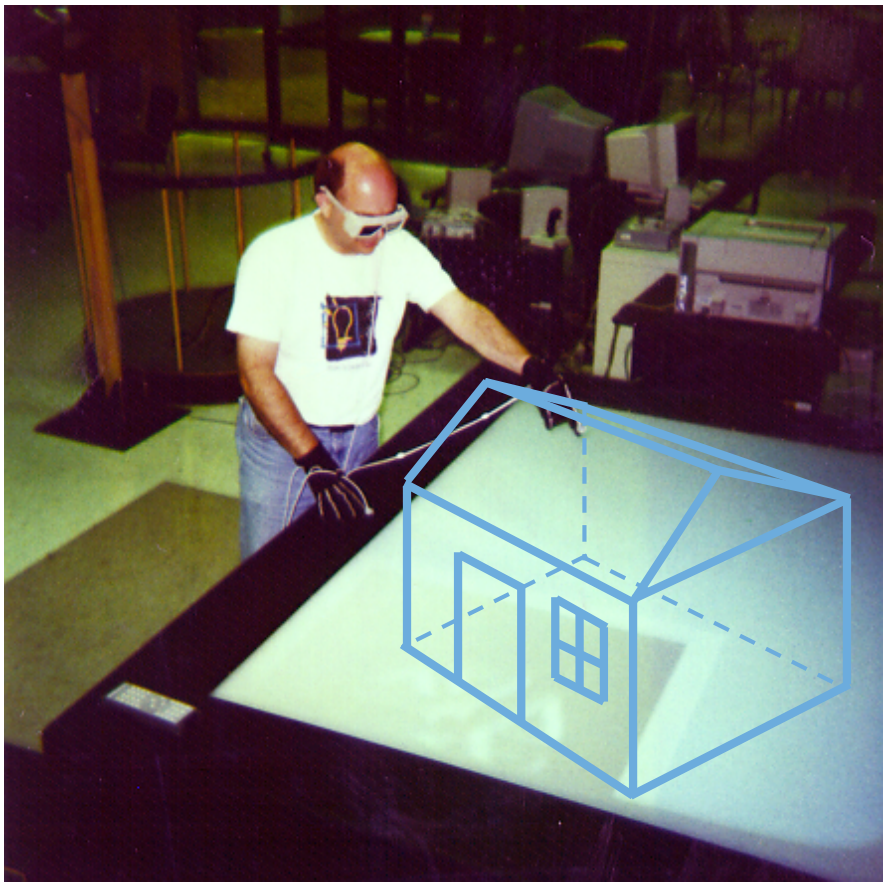
Immersive Technology

- Multi-screen Projection of stereoscopic images
- Cave Automatic Virtual Environments (CAVE)
  - Provides the illusion of immersion by projecting stereo images on the walls and floor of a room-sized cube.
  - A head tracking system continuously adjust the stereo projection to the current position of the leading viewer.





Immersive Technology



- Single large stereoscopic display
  - Projection-based
  - Head-tracked
  - Possible tracking of hands and arms.
  - Brings virtual objects into the physical world

Immersive Technology

- Data Glove
  - Outfitted with sensors on the fingers as well as an overall position/ orientation tracking equipment.
  - Enables natural interaction with virtual objects by hand gesture recognition.

- Glove-Free Hand-Tracking
  - Leap Motion

Other Characteristics

- Head and body tracking implies that visual content is always computed and rendered in “real time” (10-60 frames/second).
- In virtual reality you have a sense of, and interact with, three-dimensional things as opposed to pictures or movies of things.
- Usually needs Ultra HD rendering, e.g., for the 360 spherical stereoscopic images

https://www.youtube.com/watch?v=To-sQC_g4h0

What are the primary intellectual components that create a virtual environment?

- Hardware / Technology
- User's Perspective (the environment that is experienced)
- System Software Design
- Interaction Techniques

Hardware / Technology

- What display modalities and technologies will I use?
- What sensor modalities and technologies will I use?
- What is my computation environment?
- How many active users do I wish to accommodate?

User's perspective

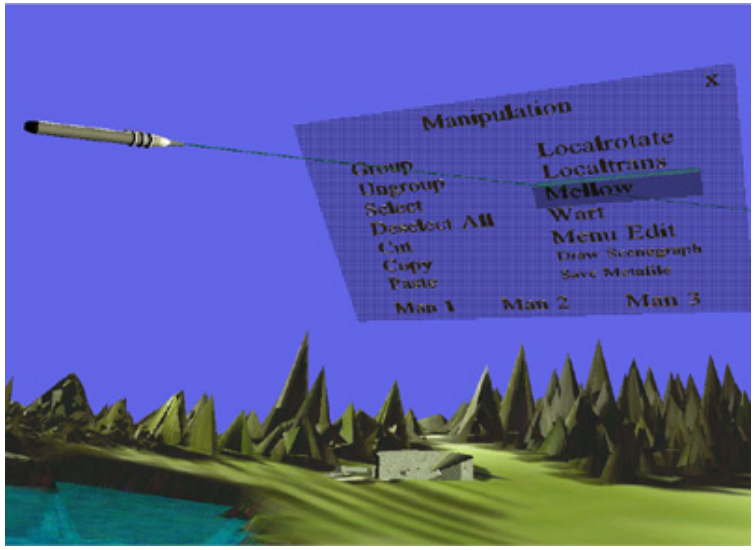
- Setting
- Objects in world
- Other participants
- Active/Passive
  - Factory Simulation
  - Architectural Walkthrough

System Software Design

- Software structures that run the virtual environment
  - Rendering group
    - Graphics, audio, haptic
  - Sensor polling group
    - Separately poll each sensor hardware subsystem
  - Computation group
    - Manage the state of the environment

Interaction Techniques

- Do I interact with the environment?
- How do I interact with the environment?
- Not the same as what devices I use



Applications:

simulation & training

gaming

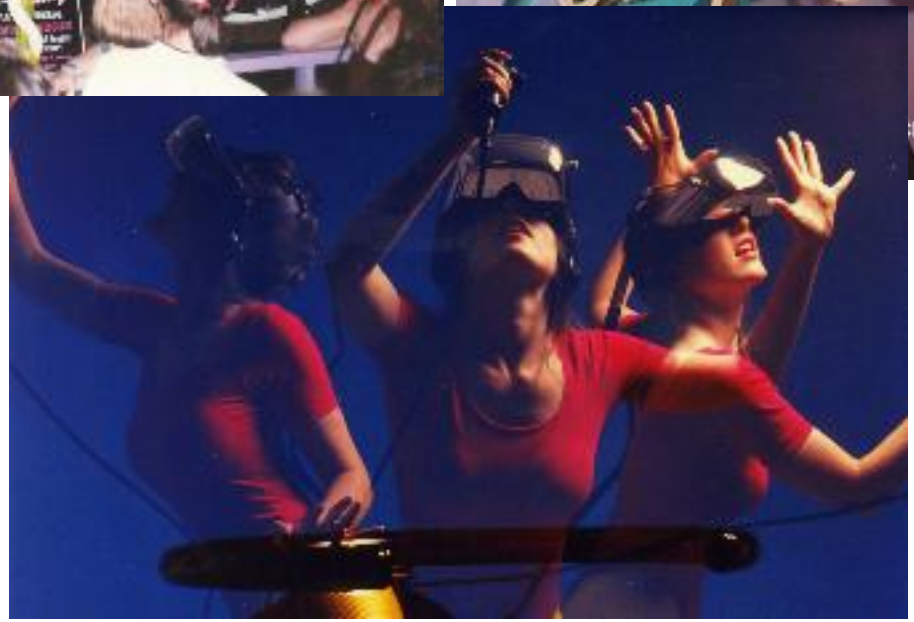
visualization & entertainment

robotic surgery

Simulation and Training – Military

Simulation and Training – NASA

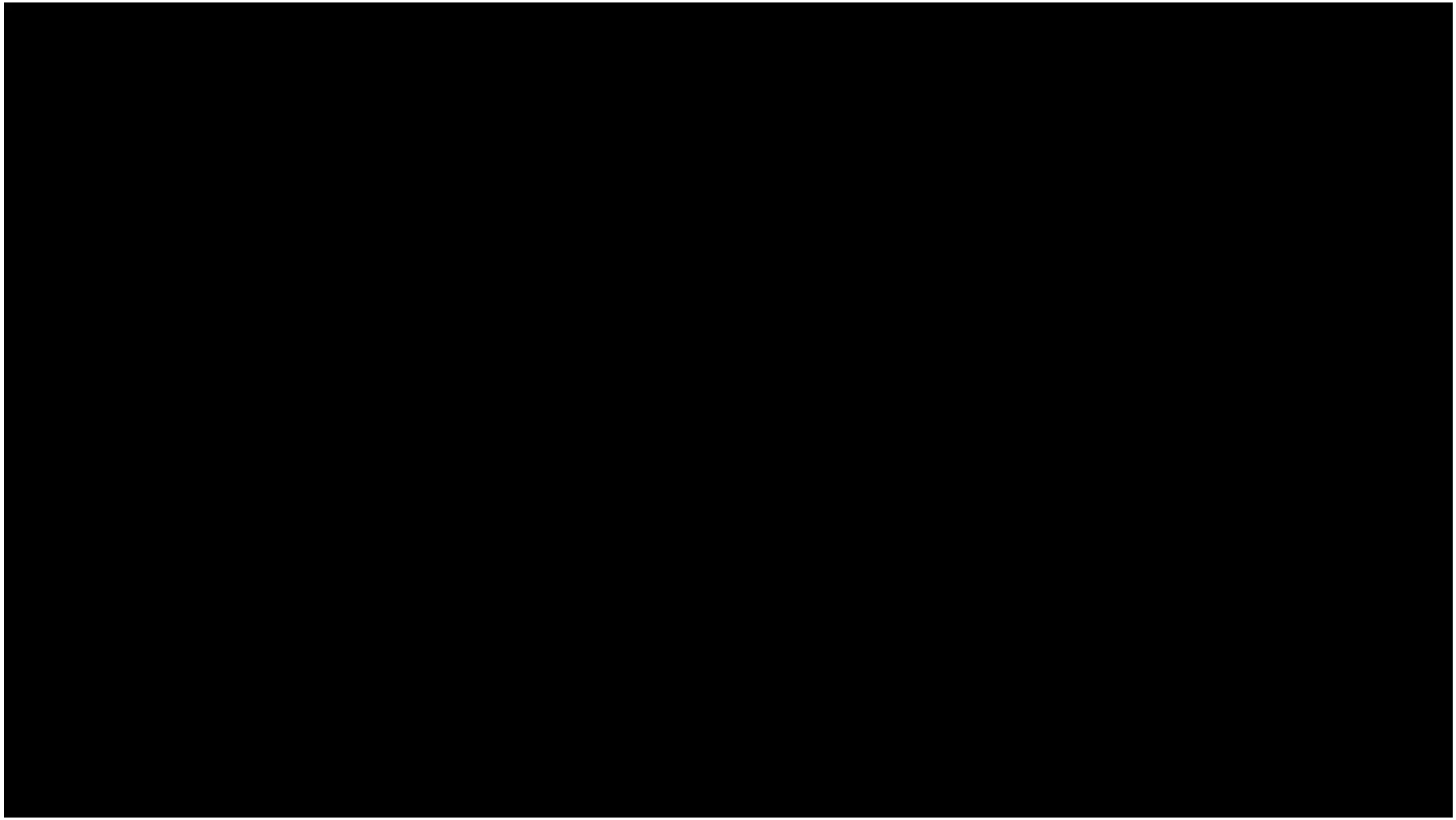
Visualization and Entertainment



Visualization and Entertainment

Design Visualization

Clinical Virtual Reality



Applications: Summary

1. **Psychology research** - conduct psych studies in VR
2. **Games** - create an immersive game
3. **Training and Education** - train or learn a skill in VR
4. **Art** - Interactive Art exhibit
5. **Data Visualization** - navigate multi-dimensional data
6. **Telepresence** - present the user in an another time or location (e.g. teleconference
7. **Phobia Treatment** - exposure therapy to fear (e.g. fear of heights)
8. **Architectural and Design evaluation** - explore a 3d model of a structure
9. **VR and Journalism**

simulation & training

visualization & entertainment

gaming

robotic surgery

Other Interesting Stuffs

Oculus DK2 Teardown

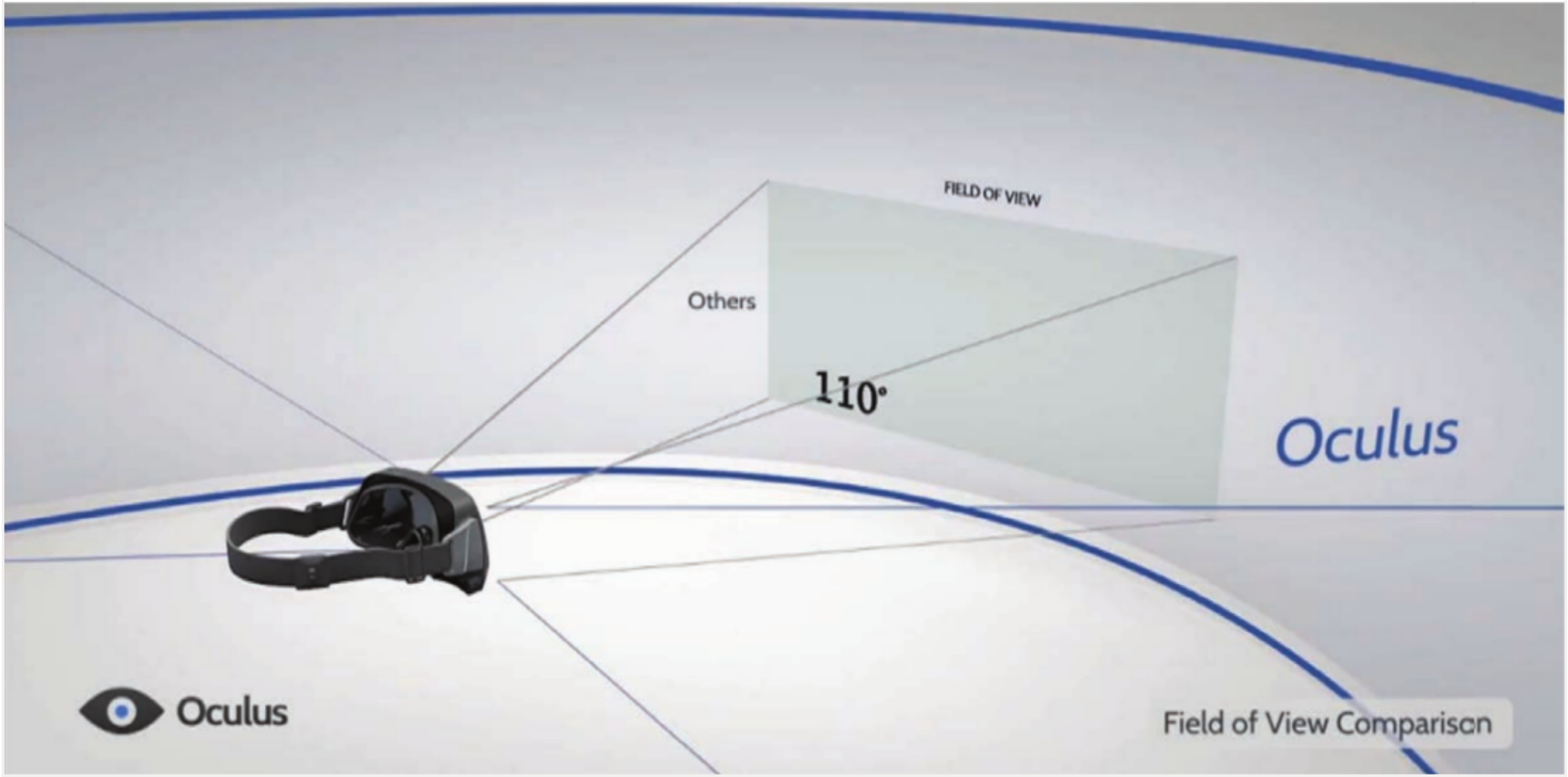
- Samsung 5.7” AMOLED: 1920x1080px, 75Hz
- 2 sets of lenses (for different prescriptions)
- InvenSense 6-axis IMU
- ARM Cortex-M3 MCU
- …

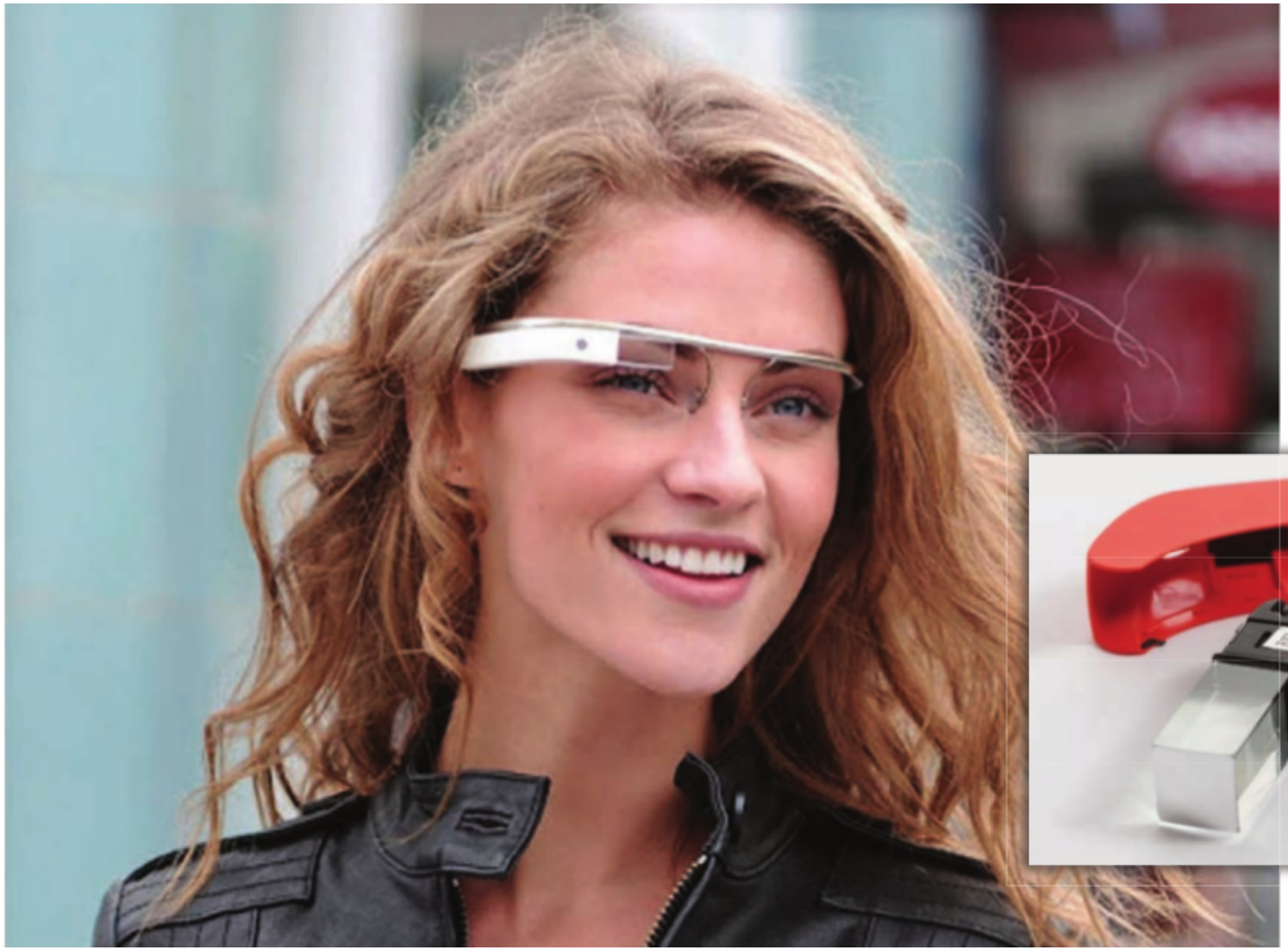
key factors:

low latency & wide fov!

https://www.ifixit.com/Teardown/Oculus+Rift+Development+Kit+2+Teardown/27613

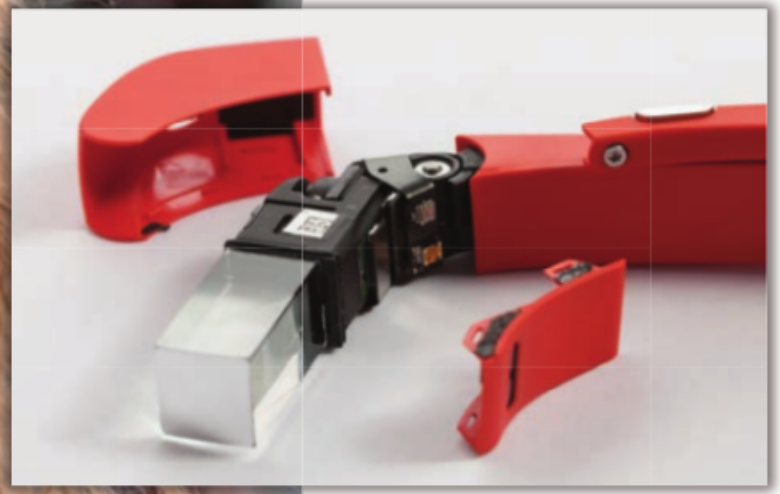
Field of View!





Google Glass

small!



Microsoft Hololens – Time of Flight Sensor Array

Demo – Lenovo Phab2

Future of VR and AR

- Still in the early stage
- Hardware
- Research in Computer graphics, vision, HCI