Stereo Vision and Virtual Reality

Multimedia Techniques & Applications

Yu-Ting Wu

Outline

- Stereo vision
- Virtual reality

Stereo Vision

Why Human can Perceive 3D

- **Physiological perception**
- **Psychology perception**

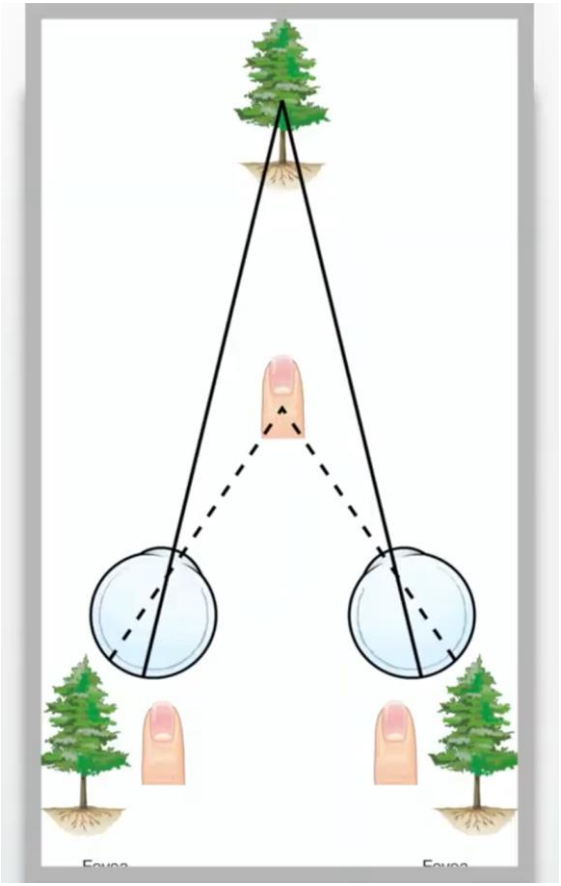
Materials from https://www.youtube.com/watch?v=ZKZfBYZ91e0

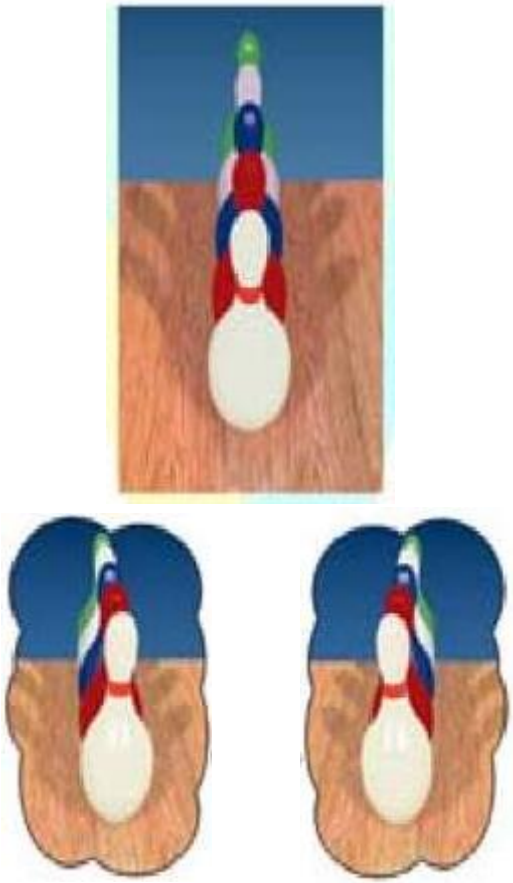
Physiological Perception

- **Binocular display**
- **Convergence**
- **Motion parallax**
- **Accommodation**

Binocular Display (Stereo)

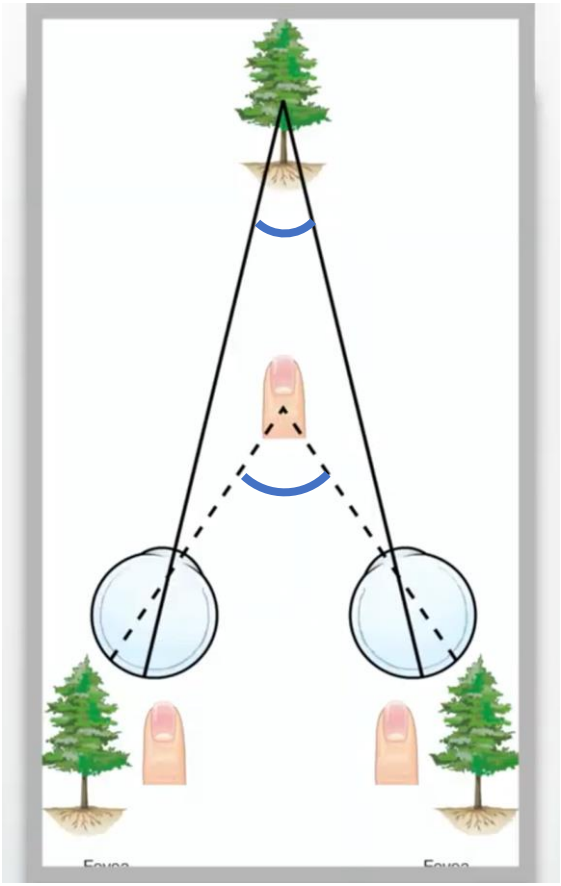
- Left and right eyes see different aspects of the same objects





Convergence

- Independent control of eye's viewing direction



Motion Parallax

- Nearby objects appear to move faster across the view

Accommodation

- Variable focus control

Psychology Perception

- **Linear perspective**
- **Occlusion**
- **Shading (and shadows)**
- **Texture**
- **Prior knowledge**

Linear Perspective

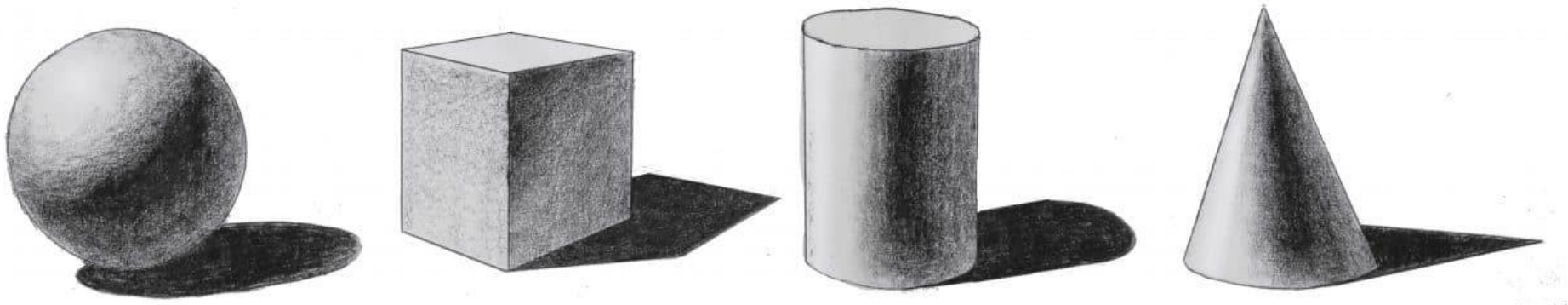
- Parallel lines converge at a distant point on horizon

Occlusion

- Invisible portion of objects behind an opaque object

Shading (and Shadows)

- Shading and shadows cast by an object gives a strong depth queue



Texture

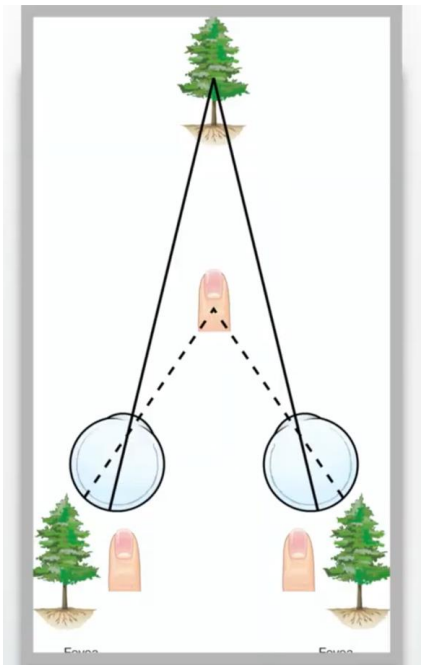
- Surface feature on objects can be used to infer 3D shape and distance

Prior Knowledge

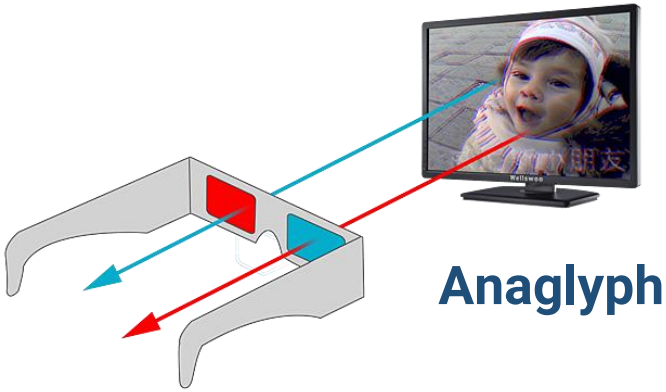
- Common structure of objects can be used to infer depth cues

How a 3D Display Works

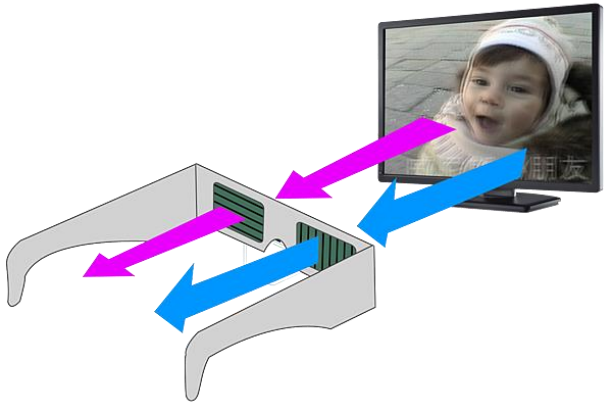
- How to enable people to perceive 3D from a 2D content (for example: screen) ?
- Usually based on **binocular display (stereo)**
  - Use special glasses (and projectors) to let left and right eyes see different content



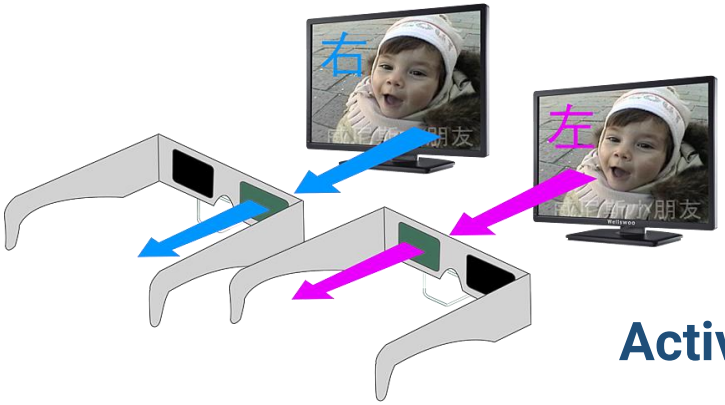
Types of 3D glasses



Anaglyph 3D glasses



Polarized 3D glasses



Active shutter 3D glasses

Images from https://wellswoo.pixnet.net/blog/post/203007334

Virtual Reality

Virtual Reality

- The Matrix (1999)
  - https://www.youtube.com/watch?v=AGZiLMGdCE0

Virtual Reality (cont.)

- The Matrix (1999)

  ‘This isn’t real?’

  ‘How do we know what we experience is ‘real’? What is ‘real’? How do you define ‘real’?’

  ‘If you’re talking about what you can feel, what you can smell, what you can taste and see then ‘real’ is simply electrical signals interpreted by the brain’.

Virtual Reality (cont.)

- Use computer technology to synthesize and simulate a 3D world that a user can explore and interact with while feeling as if he/she was in that world

Virtual Reality (cont.)

- A generalized definition

VR with head-mounted display (HMD)

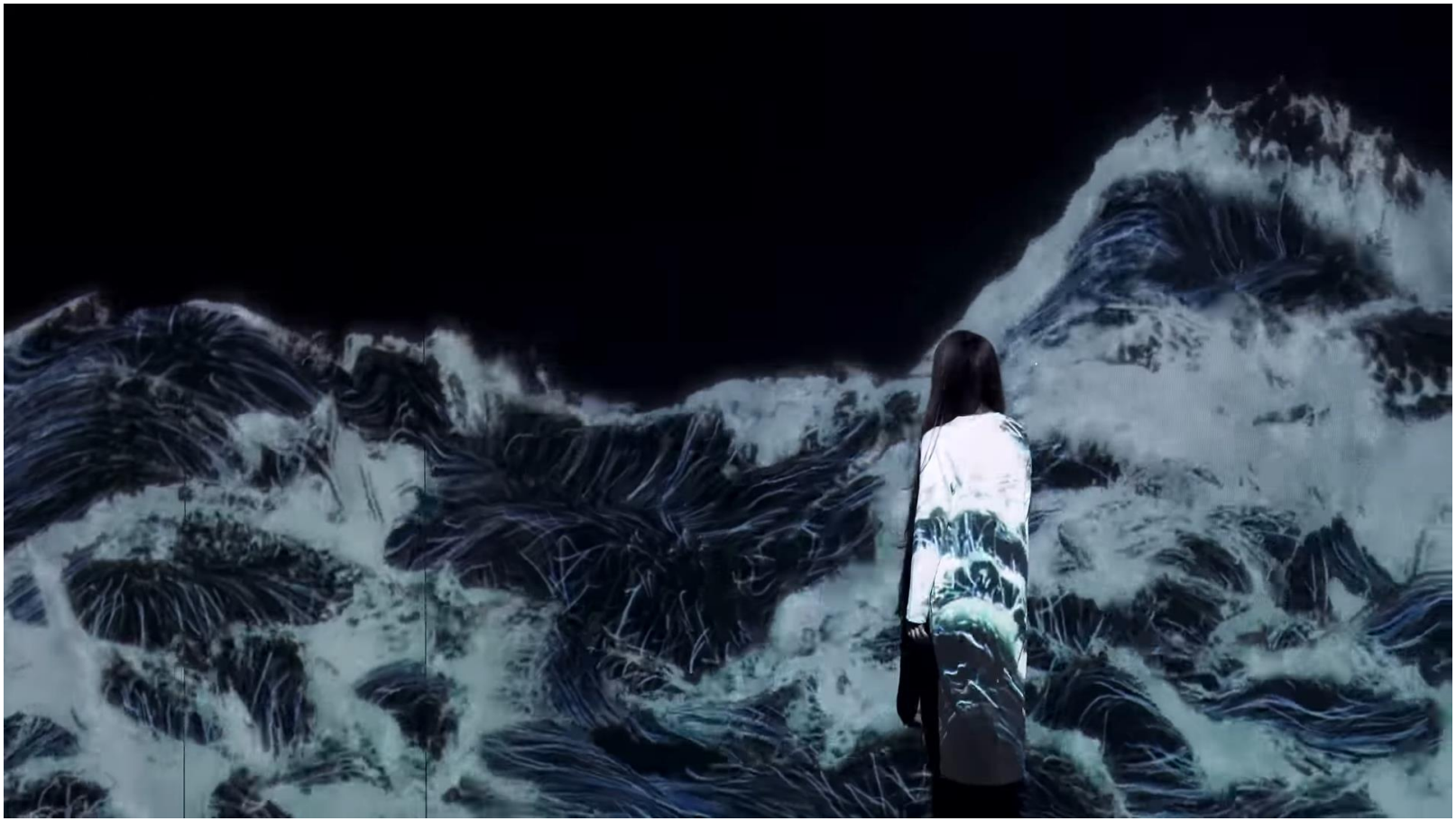
Immersive projection

Ambisonics

Materials from https://j4170149.medium.com/

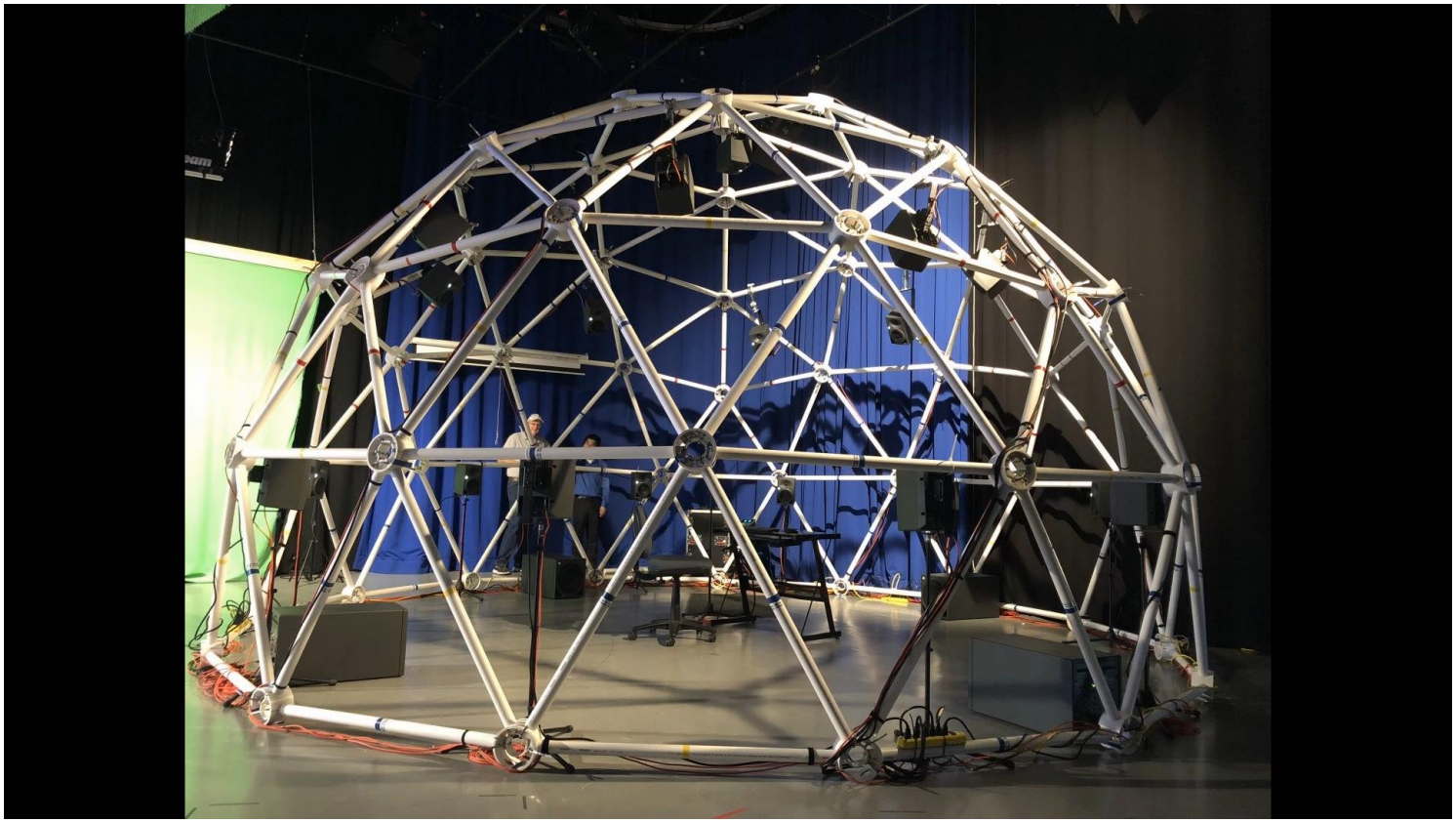
Immersive Projection

- TeamLab: https://youtu.be/tNvLFNHQ9Fg



Ambisonics

- Geodesic sound dome at MTSU: https://youtu.be/OzvZcisDq9Y



Head-mounted Display VR

- The first VR with head-mounted display (1966)

Head-mounted Display VR (cont.)

- Arizona Sunshine:

Head-mounted Display VR (cont.)

- Richie‘s Plank: https://youtu.be/4M92kfnpg-k

Head-mounted Display VR (cont.)

- SunshineCity: https://youtu.be/1WJ8Od8FZ_0

Head-mounted Display VR (cont.)

- Puccho an 4D googles: https://youtu.be/eN5bW8fgJuU

VR Applications

- Entertainment

VR Applications (cont.)

- Art creation

VR Applications (cont.)

- Training

VR Applications (cont.)

- Education

VR Applications (cont.)

- Healthcare

VR Applications (cont.)

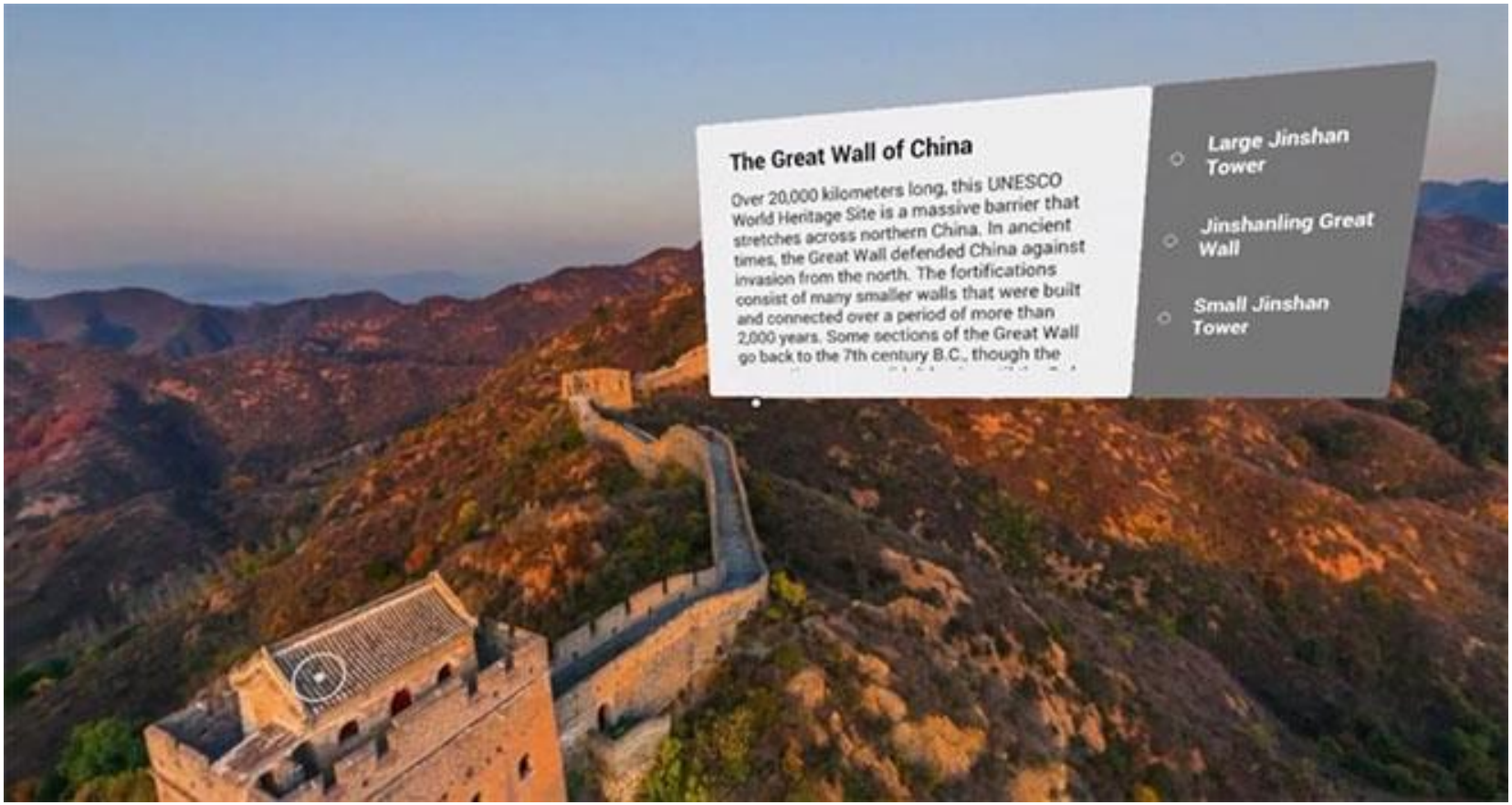
- Conferencing

VR Applications (cont.)

- Social

VR Applications (cont.)

- Tourism



VR Applications (cont.)

- Shopping

VR Applications (cont.)

- Real estate

Assess VR Experiences

Based on *"Defining Virtual Reality: Dimensions Determining Telepresence"*, Jonathan Steuer, Communication in the Age of Virtual Reality 1995

- **Vividness (Immersion)**
  - The representational richness of a virtual environment (the way info is presented to the senses)

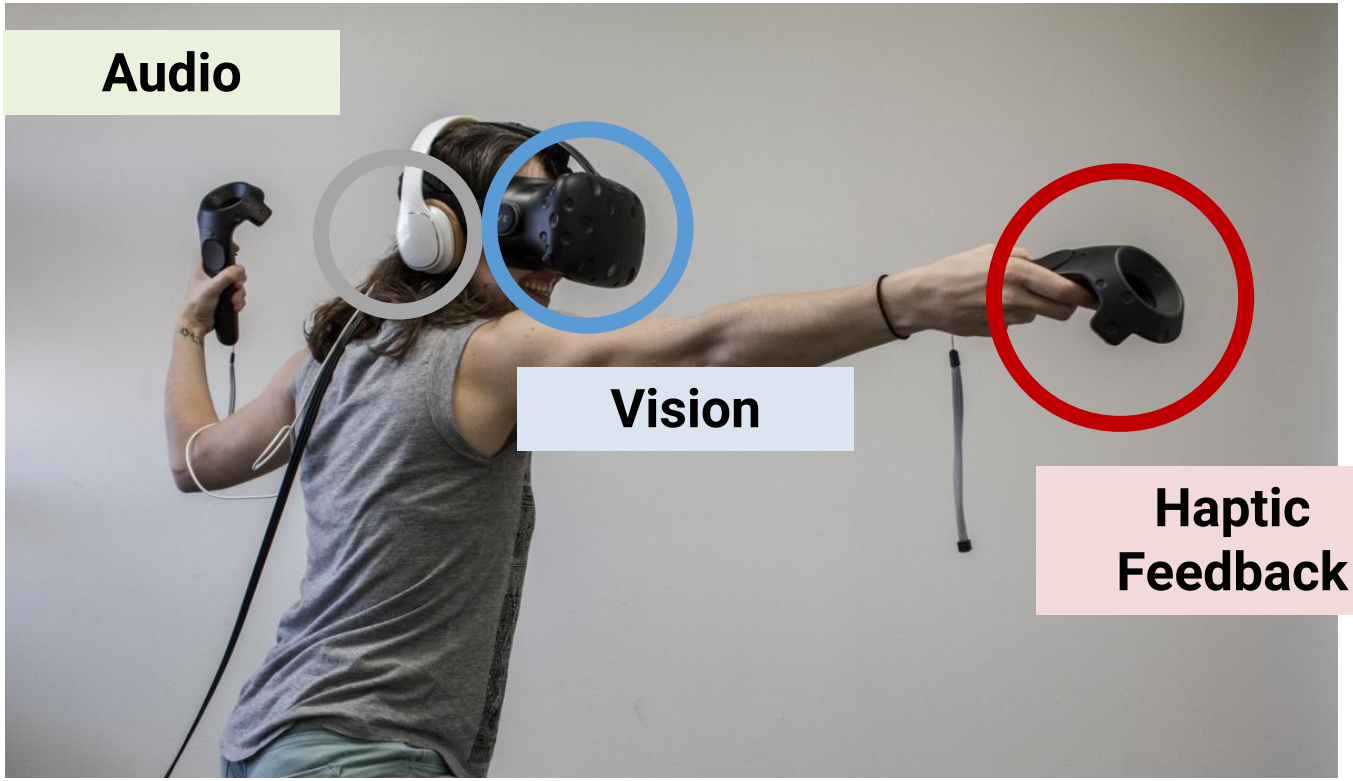
- **Interactivity**
  - The extent which users can participate in modifying the form and content of a virtual environment in real time

Factor of Vividness

- **Breadth of information**
  - Number of sensory dimensions simultaneously presented by the virtual environment
- **Depth of information**
  - The quality of data a user receives when interacting in a virtual environment

Factor of Vividness (cont.)

- **Breadth of information**
  - Number of sensory dimensions simultaneously presented by the virtual environment



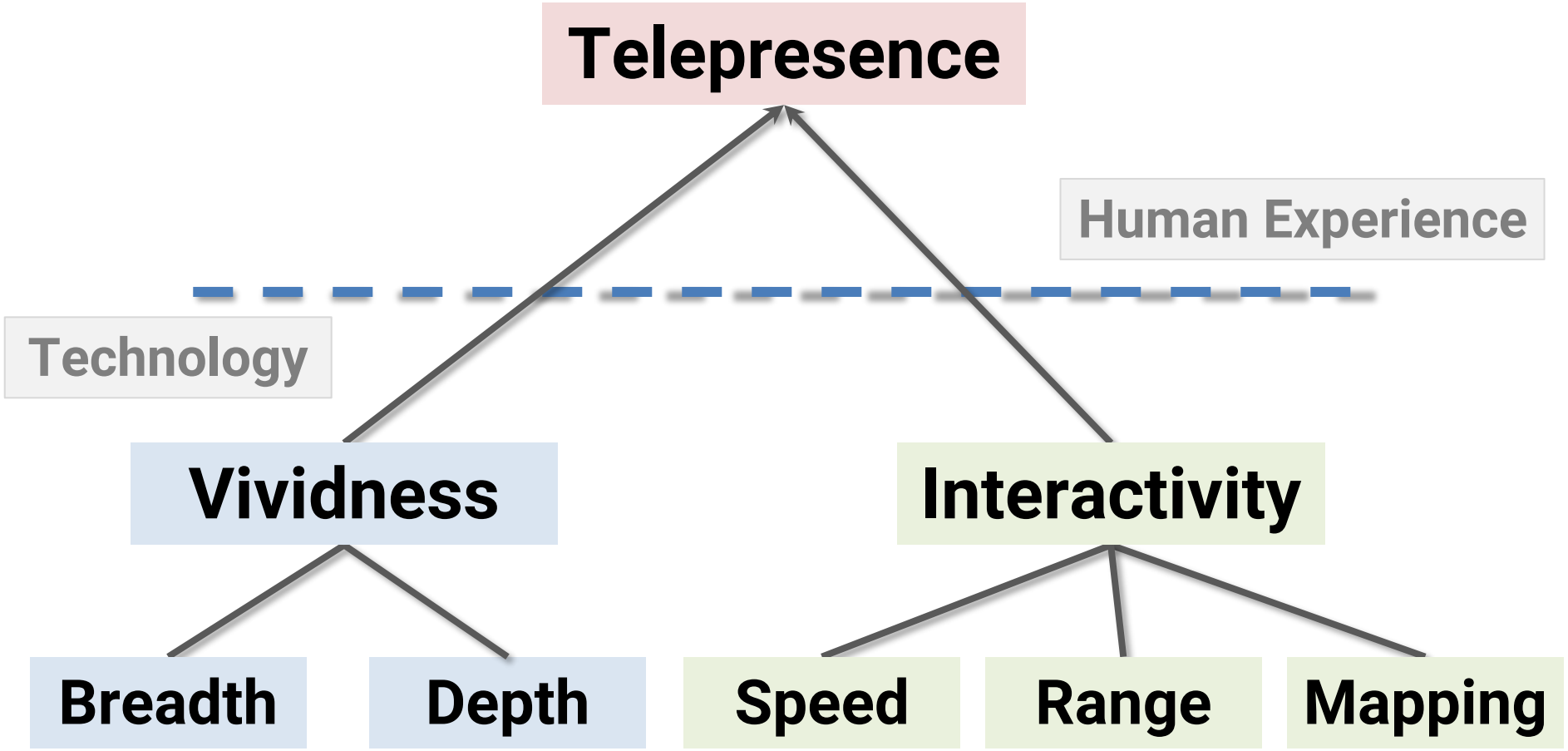
Factor of Vividness (cont.)

- **Depth of information**
  - The quality of data a user receives when interacting in a virtual environment

Factor of Interactivity

- **Speed**
  - The rate at which input can be assimilated into the mediated environment
- **Range**
  - The number of possibilities for actions at any given time
- **Mapping**
  - The abilities of a system to map its controls to changes in the mediated environment in a natural and predictable manner

Assess VR Experiences



Basic Components of VR

- A VR technique should at least include
  - Three-dimensional object that appear to be life-sized from the perspective of user

➔ **Stereoscopic simulation, rendering, and display**

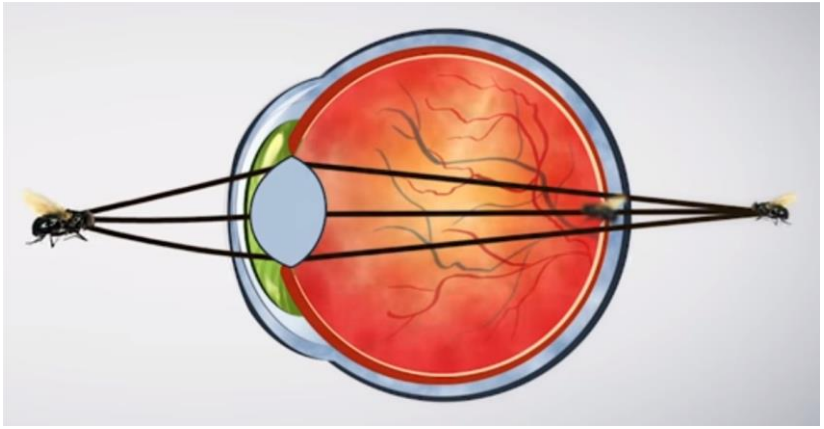
  - The ability to track a user's motions, particularly the head movements

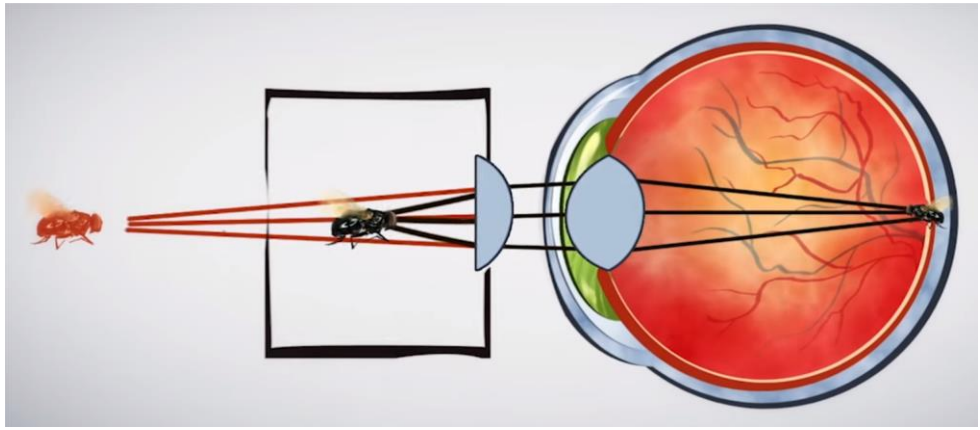
➔ **Tracking system**

Head-mounted Display

Head-mounted Display

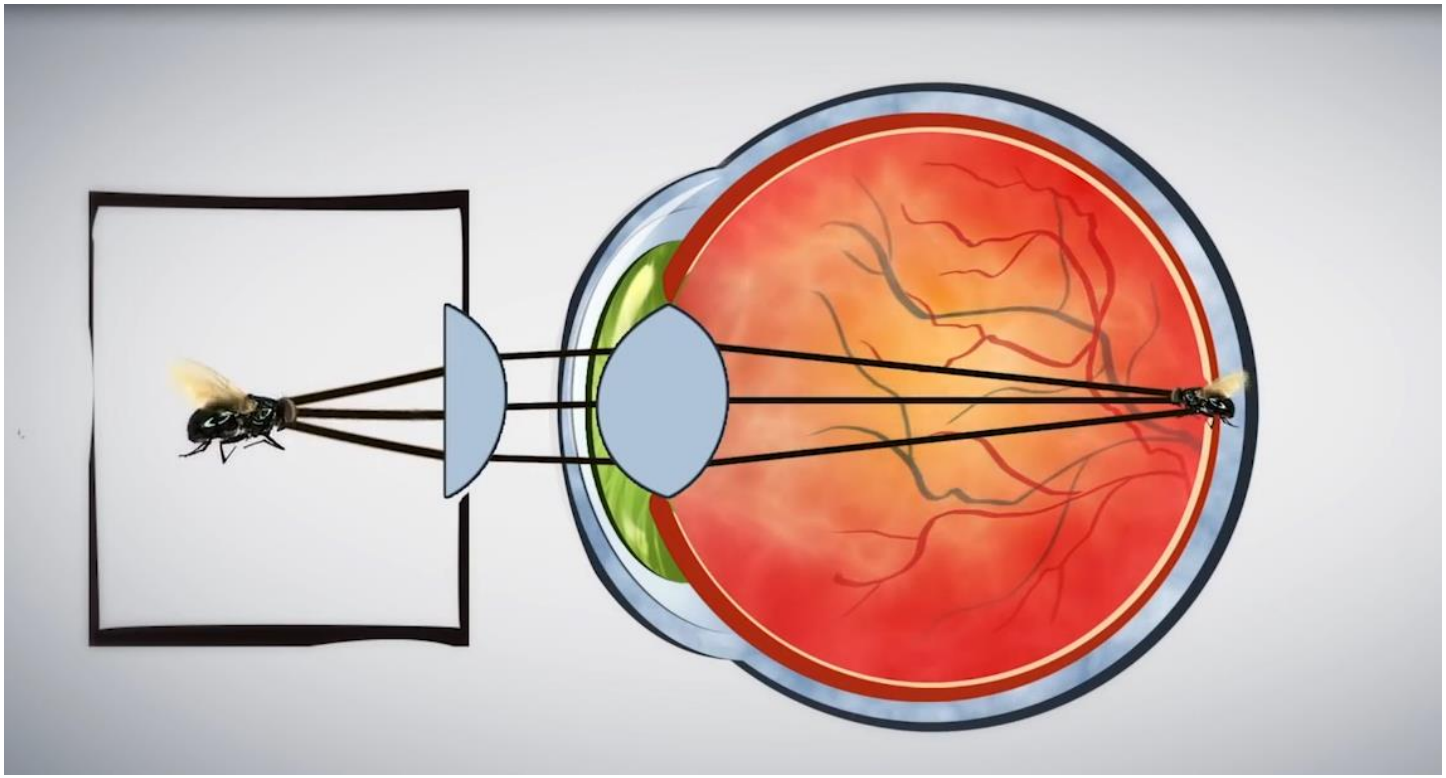
- Human eyes cannot see the very close-by objects (screen) clearly
- Need lenses for focusing





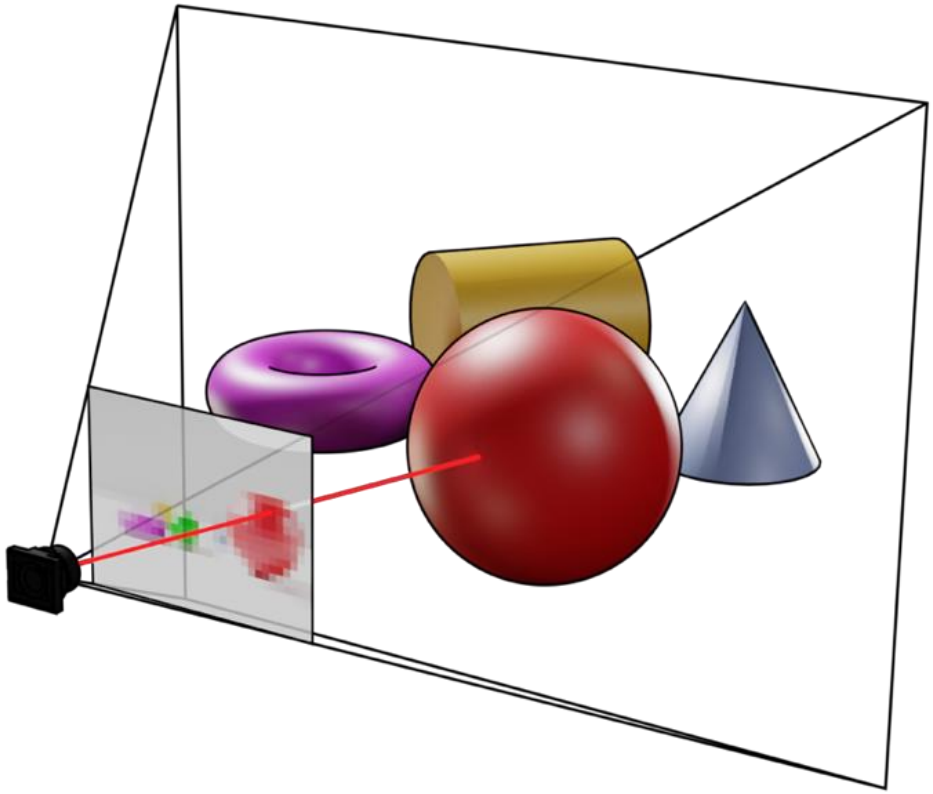
Head-mounted Display (cont.)

- How lenses for VR HMD work
  - https://youtu.be/NCBEYaC876A



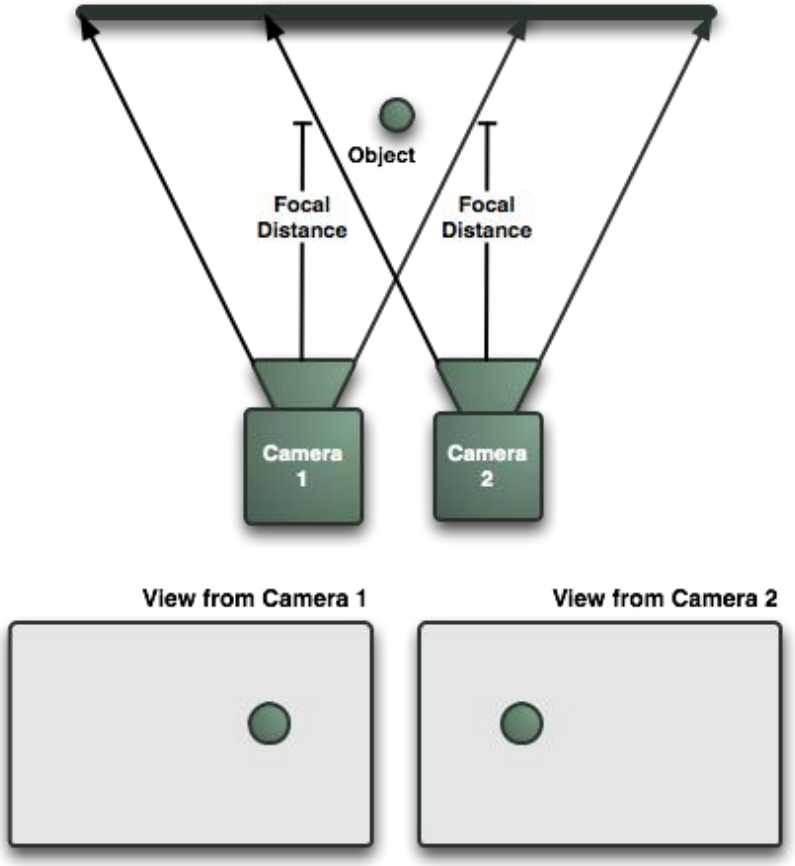
Stereo Simulation

- Based on binocular display

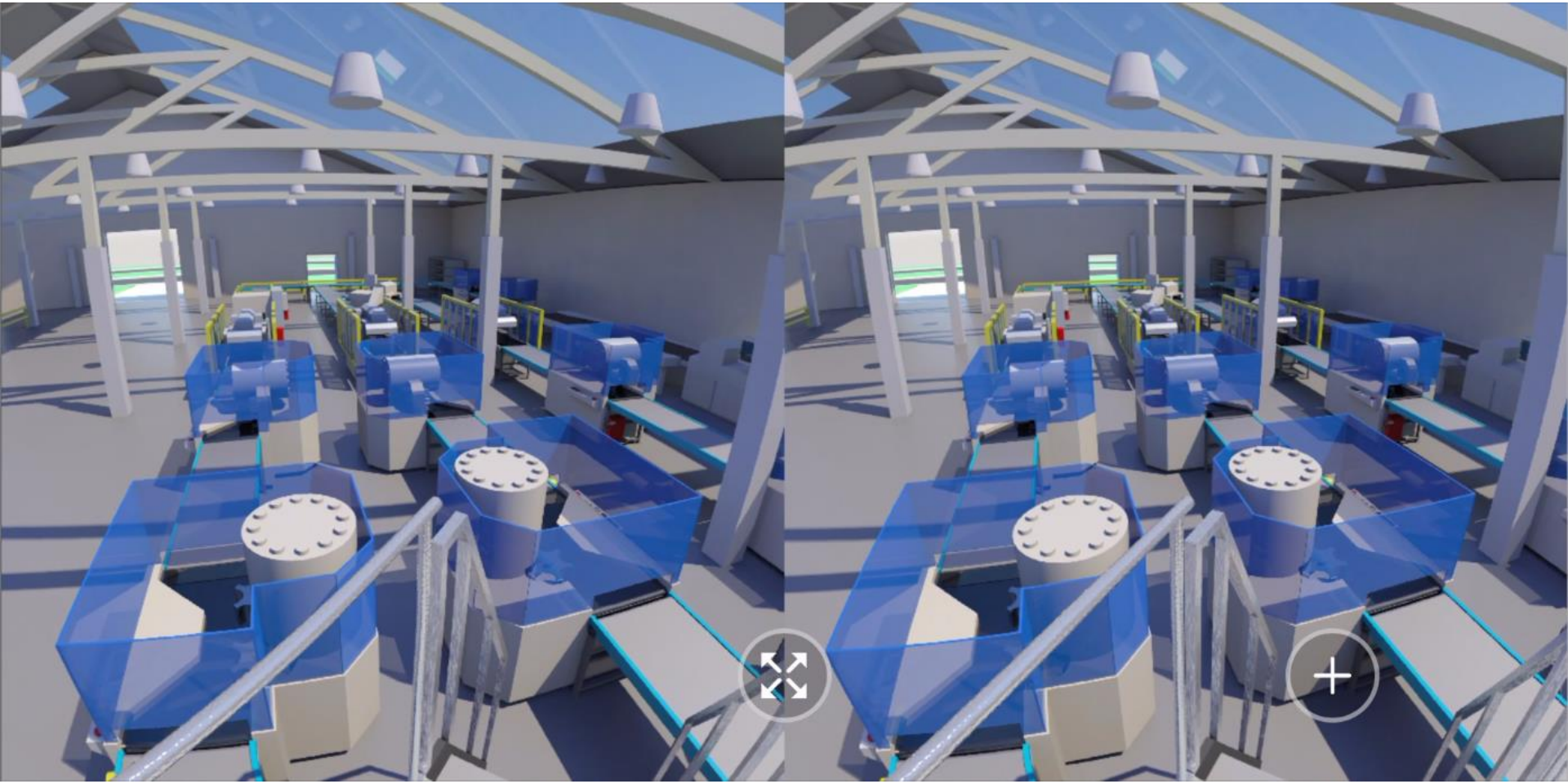


Stereo Simulation (cont.)

- Based on binocular display



Stereo Simulation and Rendering



Stereo Simulation, Rendering, and Display

Stereoscopic Simulation & Rendering

Stereoscopic Display

Tracking System

- Degree of freedom

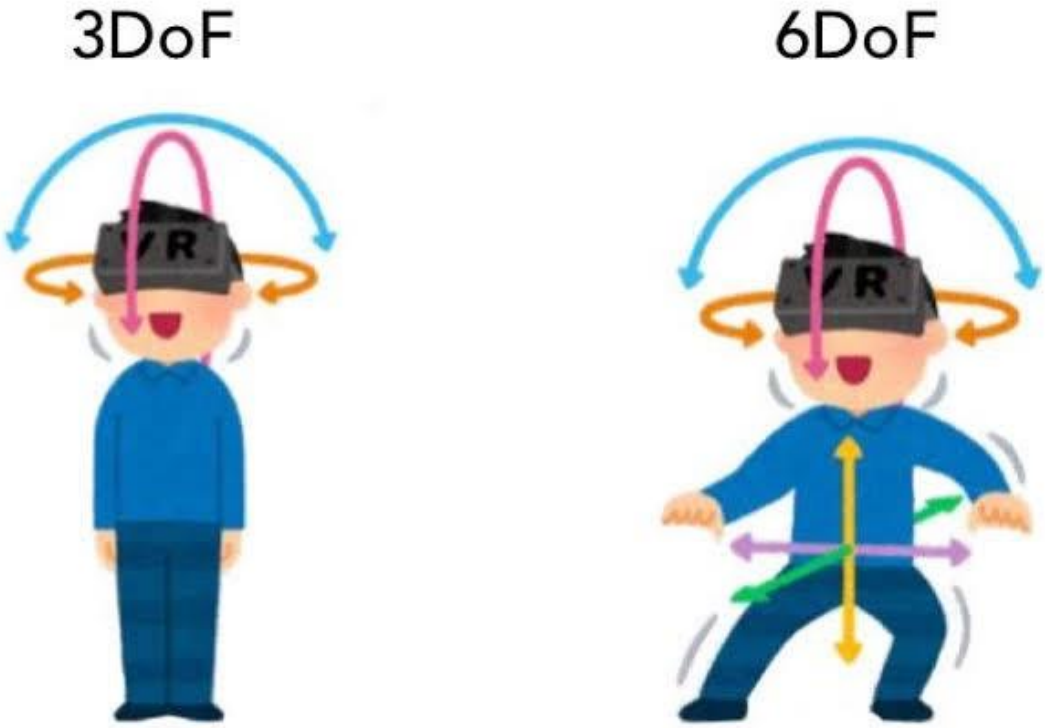
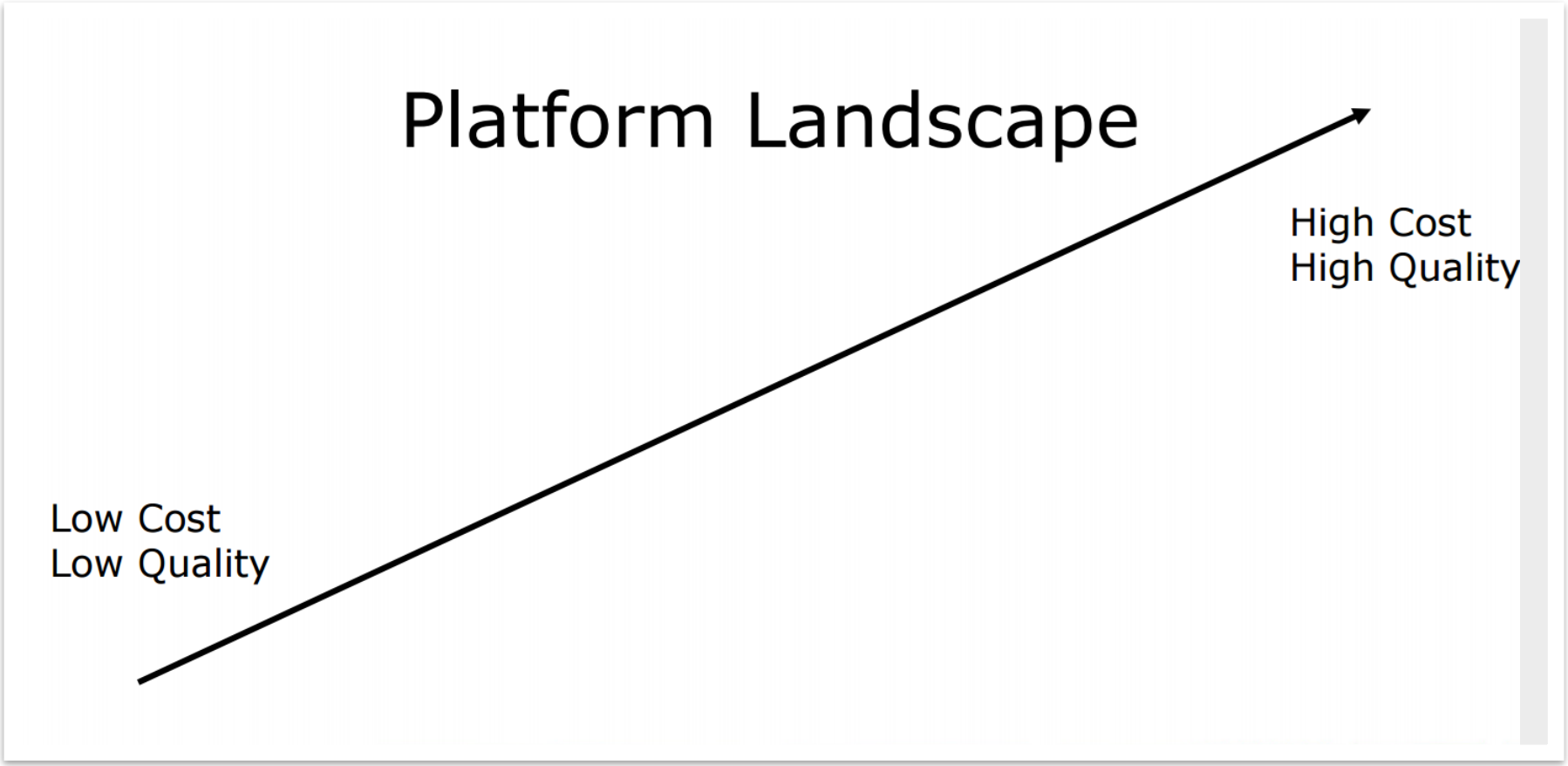


Image from
https://toast.games/4-things-to-know-about-vr-before-you-buy-a-headset/

Tracking System (cont.)

- VR devices in 2016



Tracking System (cont.)

- VR devices in 2016

3DoF

Low Cost
Low Quality

Google Cardboard

Samsung Gear VR

PlayStation VR

Oculus Rift

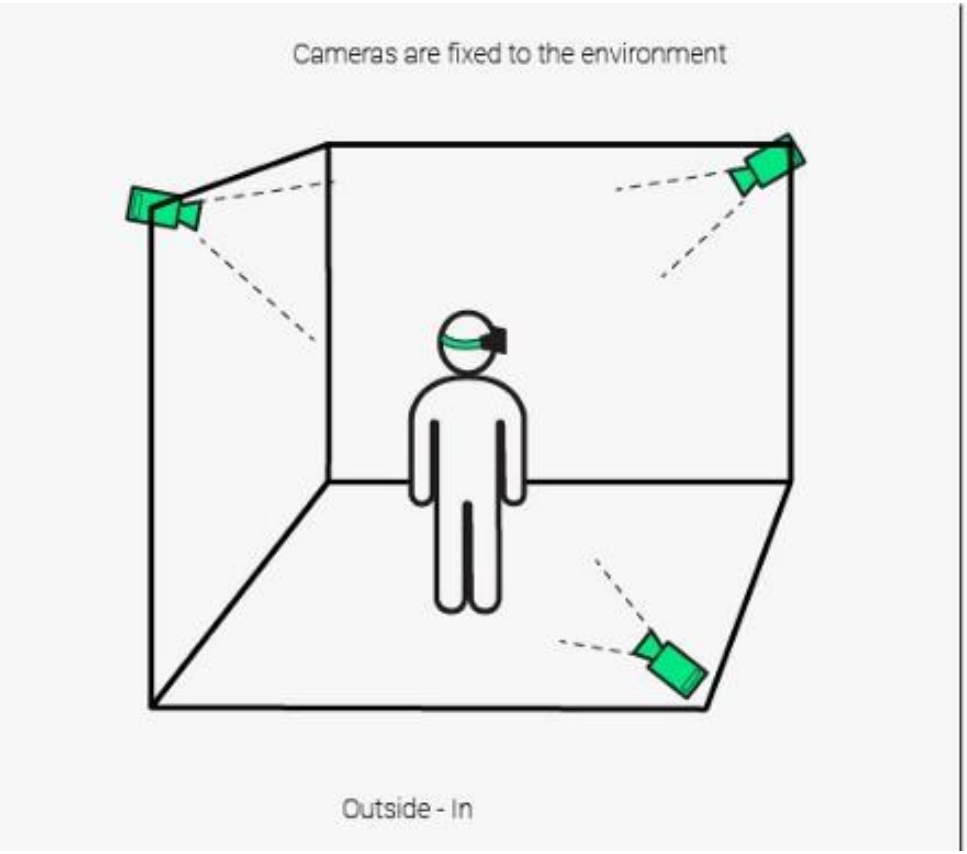
HTC Vive

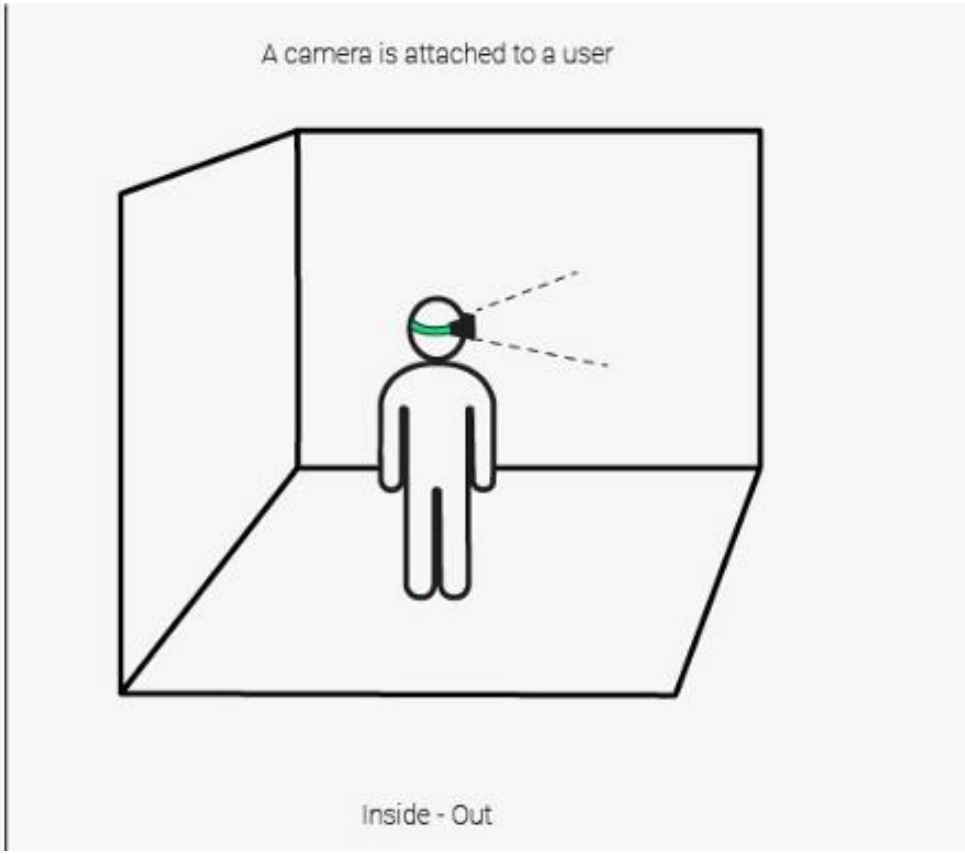
High Cost
High Quality

6DoF

Tracking System (cont.)

- Two types of tracking systems





Outside-In Tracking

Oculus Rift

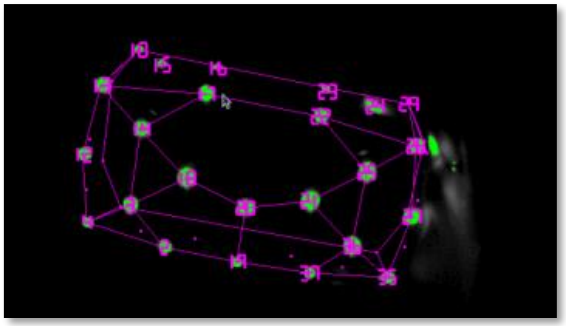
Constellation

HTC Vive

Lighthouse

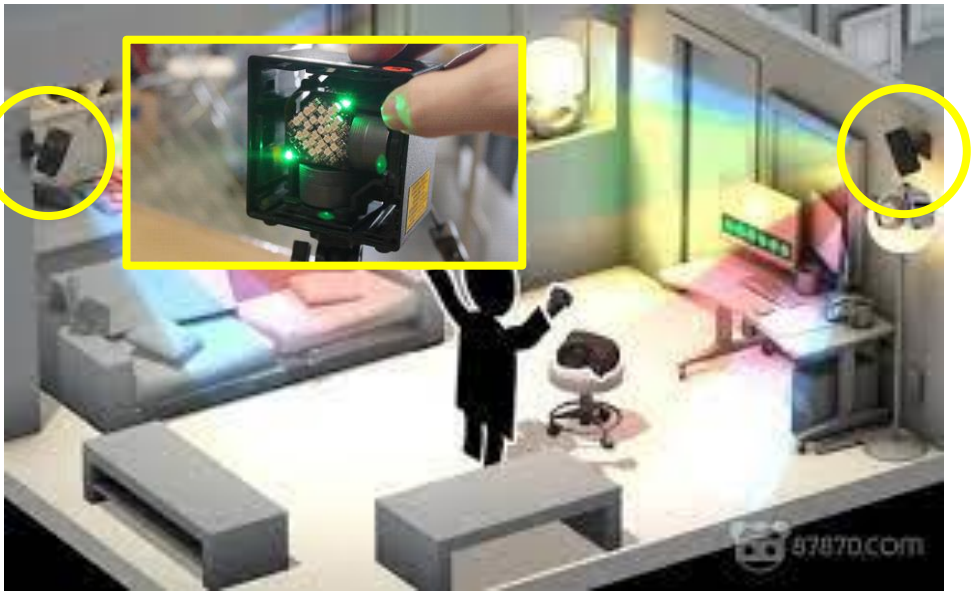
Oculus Rift: Constellation

- LEDs on HMD emits lights
- Camera captures the lights and transmits the image data to PC
- PC analyzes the data and determines HMD pose (+IMU)



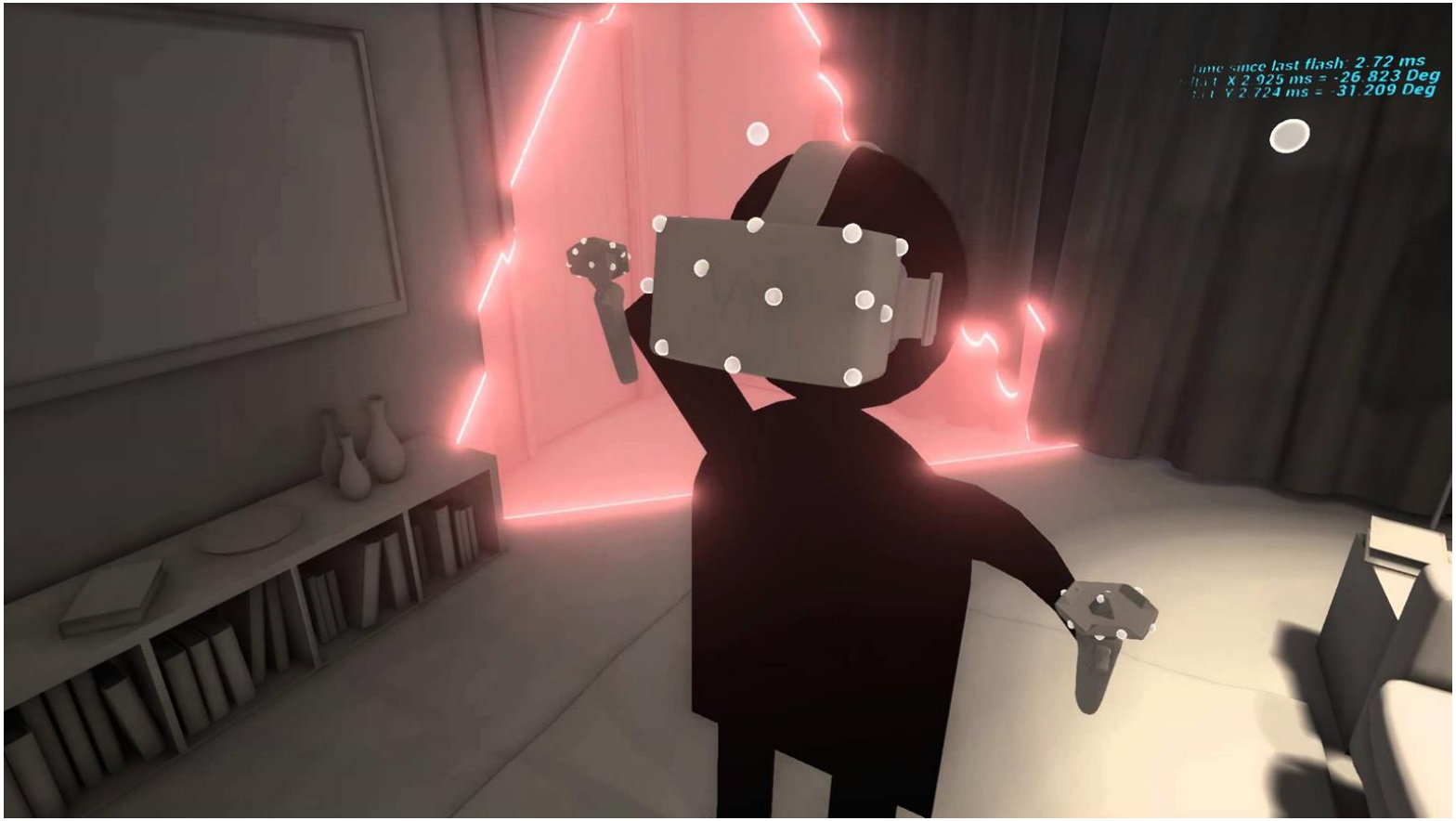
HTC VIVE: Lighthouse

- Lighthouses emit lights and X-Y lasers
- Sensors on HMD receive light and laser, and transmit the timing data to PC
- PC determines HMD pose by the timing data of sensors



HTC VIVE: Lighthouse (cont.)

- https://youtu.be/J54dotTt7k0



Inside-Out Tracking

- Based on the technique, structure of motion (SLAM)

Oculus Quest (May, 2019)

HTC VIVE Focus Series

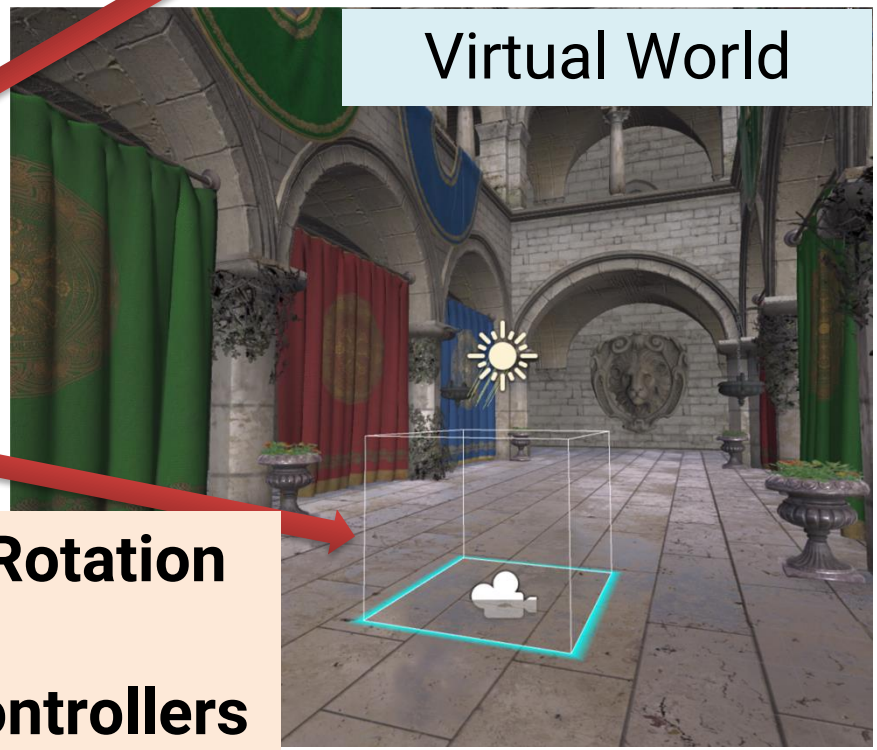
Oculus Quest 2 (Oct. 2020)

Put It All Together

Stereoscopic
Simulation & Rendering

Tracking System

Real World

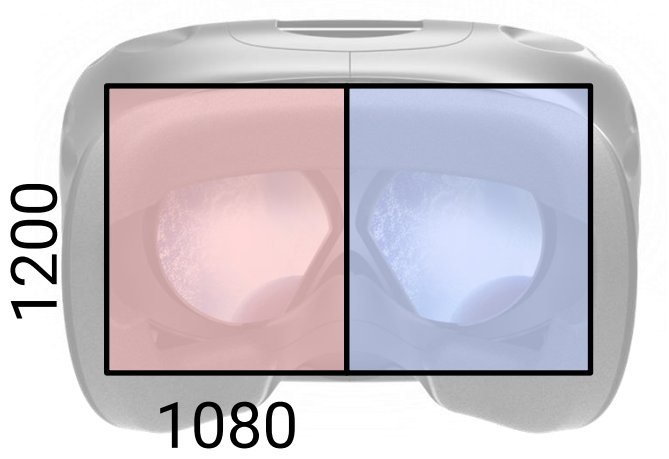


Virtual World

Position & Rotation
Of
HMD and Controllers

Major Challenges

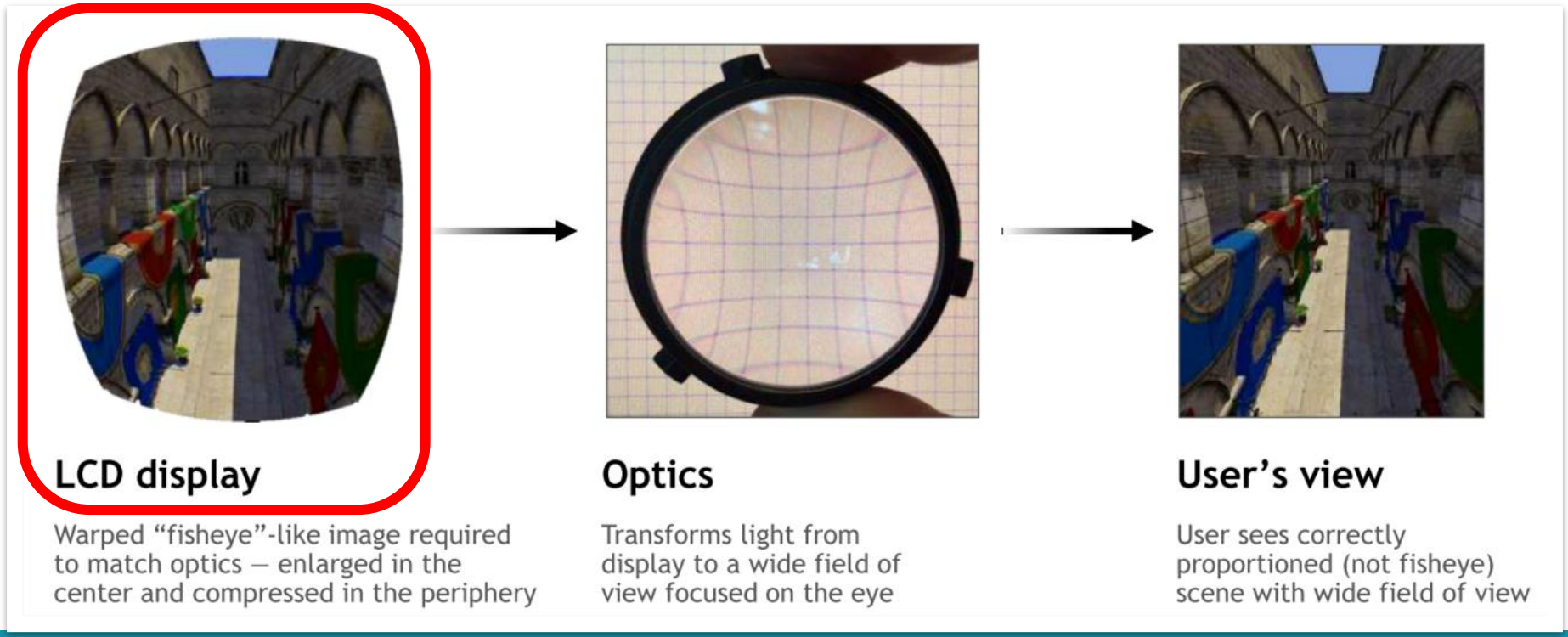
- Rendering cost
  - HMD has **high resolution** and **high refresh rate**
    - For example, for HTC VIVE, the resolution is 1080 x 1200 per-eye and 90 Hz



  - We need to render larger frame buffer (1512 x 1680 per-eye) due to the lens distortion

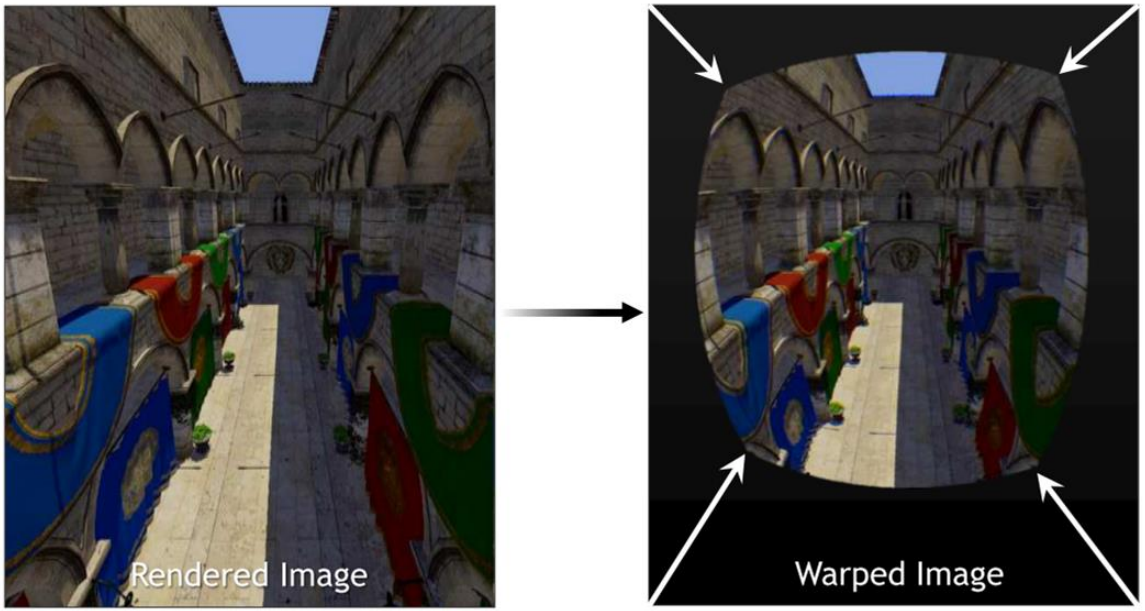
Major Challenges

- Rendering cost
  - We need to render larger frame buffer (1512 x 1680 per-eye) due to the lens distortion
    - GPU cannot natively render non-linear images



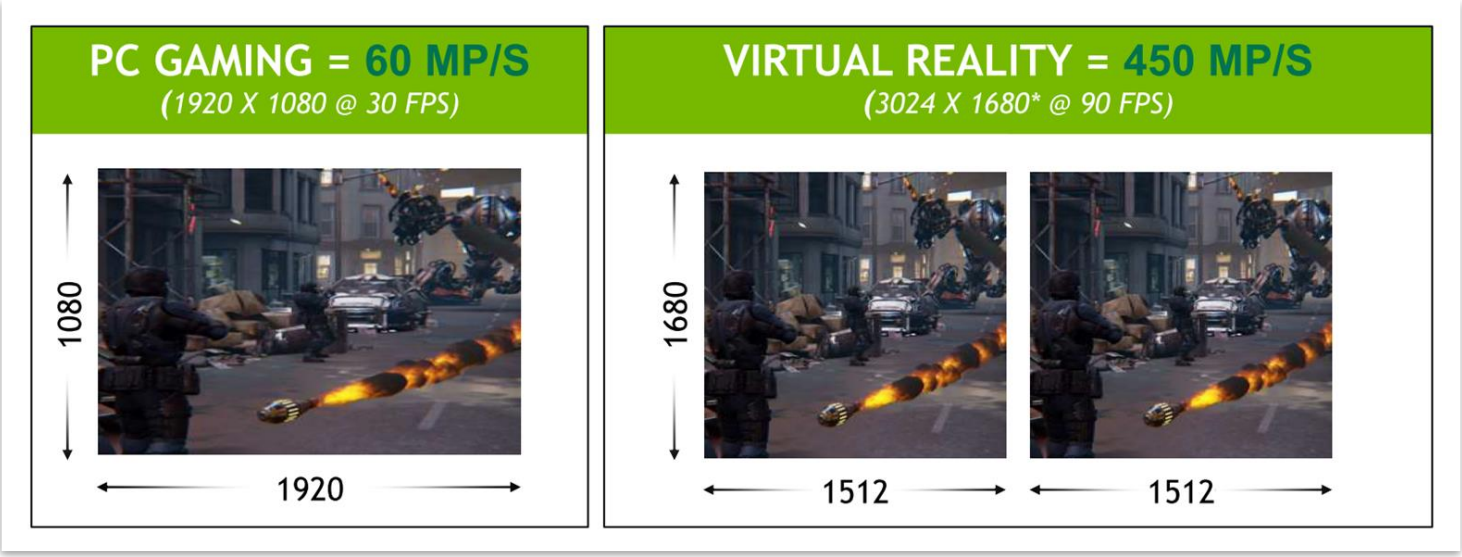
Major Challenges

- Rendering cost
  - We need to render larger frame buffer (1512 x 1680 per-eye) due to the lens distortion
    - GPU cannot natively render non-linear images
    - Current solution: render a larger image and warp it



Major Challenges

- Rendering cost
  - Rendered pixel per second



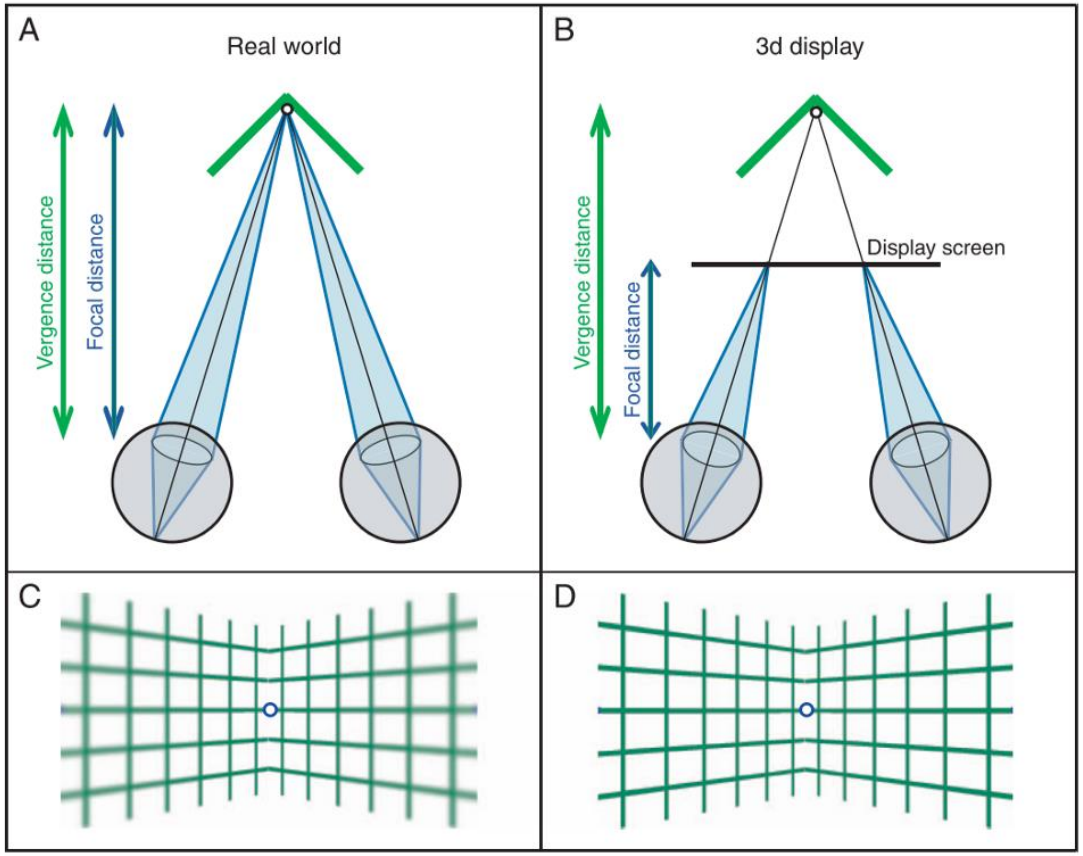
  - The rendering cost for VR is about 7 times than PC in terms of pixel number

Major Challenges

- Tethered v.s. standalone
  - Rendering quality v.s. flexibility

Major Challenges

- Motion sickness



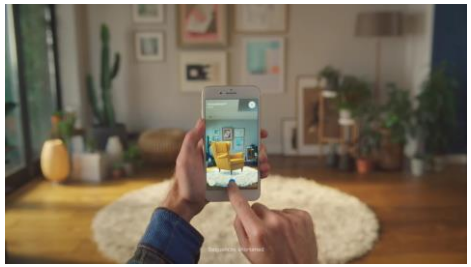
Major Challenges

- Motion sickness

Extended Reality

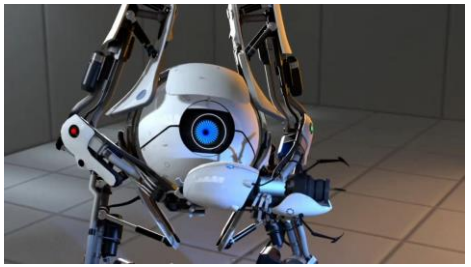
real environment — **virtual environment**

Augmented Reality (AR)



Mixed Reality (MR)

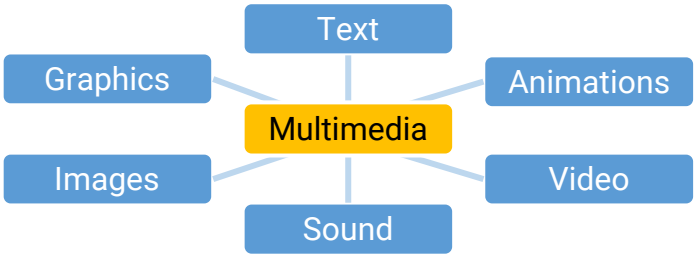
Virtual Reality (VR)



Extended Reality

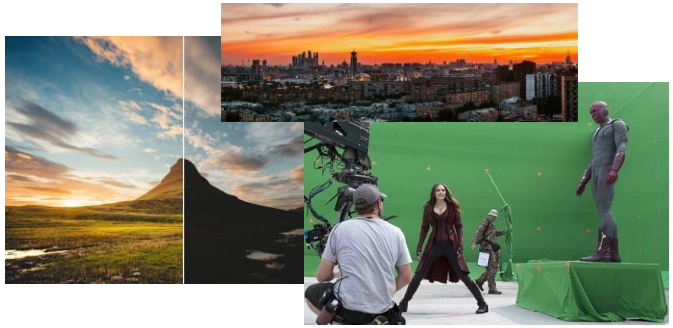
- Hyper reality: https://youtu.be/YJg02ivYzSs

Topic Map



Multimedia Fundamentals

Acquisition Devices



Real Content

Virtual Content

Virtual-Real Integration

Advanced Display Devices