
Stereo Vision and Virtual Reality
Multimedia Techniques & Applications
Yu-Ting Wu
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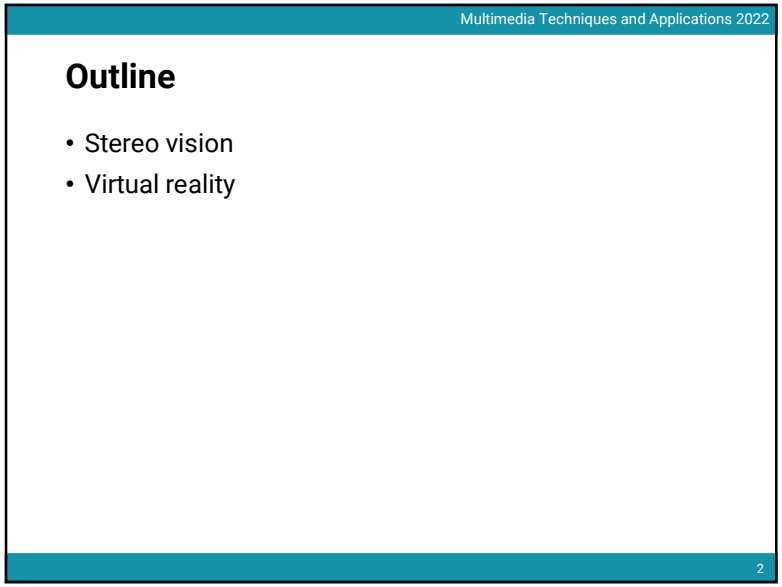
Multimedia Techniques and Applications 2022
Outline
• Stereo vision
• Virtual reality
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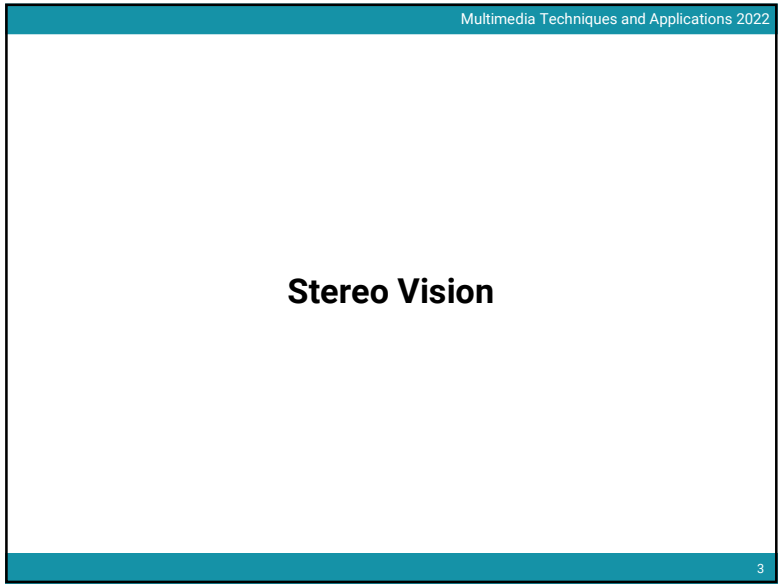
Multimedia Techniques and Applications 2022
Stereo Vision
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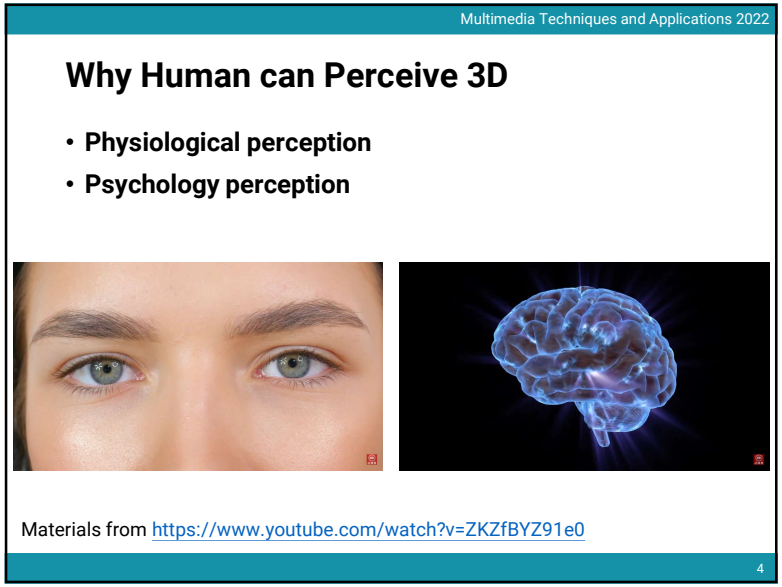
Multimedia Techniques and Applications 2022
Why Human can Perceive 3D
• Physiological perception
• Psychology perception
Materials from https://www.youtube.com/watch?v=ZKZfBYZ91e0
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Physiological Perception

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

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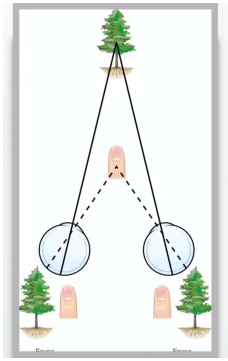
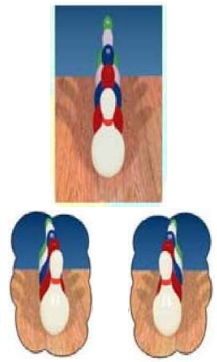
Binocular Display (Stereo)

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





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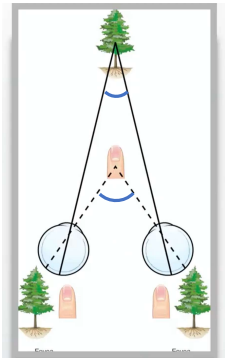
Convergence

- Independent control of eye's viewing direction



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Motion Parallax

- Nearby objects appear to move faster across the view

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Accommodation

- Variable focus control

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Psychology Perception

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

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Linear Perspective

- Parallel lines converge at a distant point on horizon

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Occlusion

- Invisible portion of objects behind an opaque object

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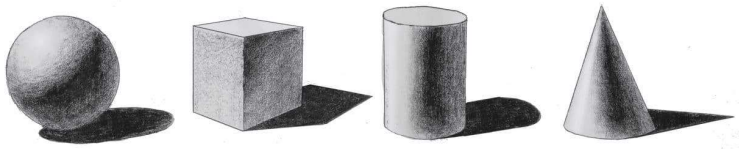
Shading (and Shadows)

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



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Texture

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

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Prior Knowledge

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

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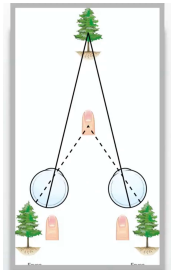
How a 3D Display Works

- 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



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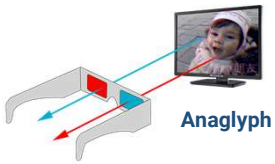
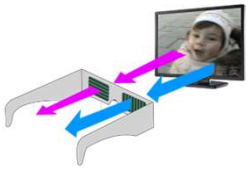
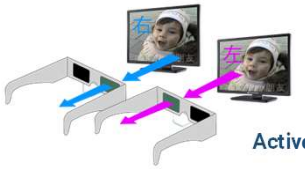
Types of 3D glasses



Anaglyph 3D glasses



Polarized 3D glasses



Active shutter 3D glasses

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

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Virtual Reality

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Virtual Reality

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

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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'.

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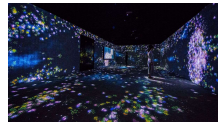
Virtual Reality (cont.)

- 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)



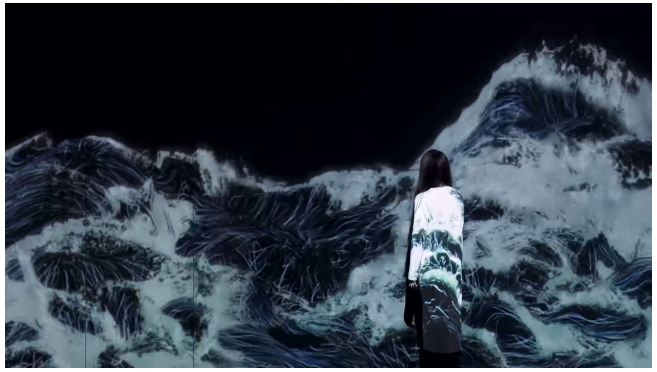
Immersive projection

Ambisonics

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

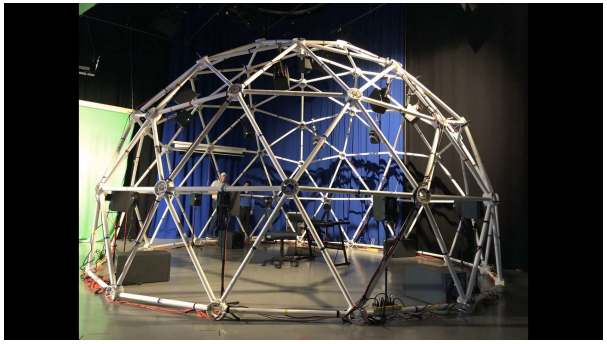
Immersive Projection

- 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)

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Head-mounted Display VR (cont.)

- Arizona Sunshine:

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Head-mounted Display VR (cont.)

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

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Head-mounted Display VR (cont.)

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

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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

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VR Applications (cont.)

- Healthcare

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VR Applications (cont.)

- Conferencing

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VR Applications (cont.)

- Social

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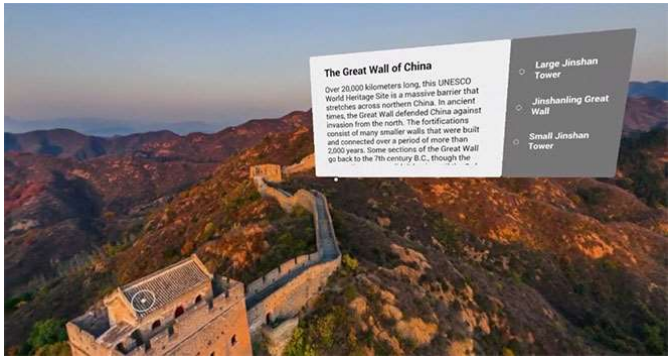
VR Applications (cont.)

- 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

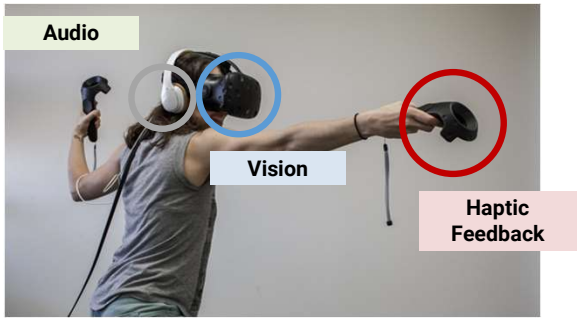
- **Vividness (Immersion)**
  - The representational richness of a virtual environment (the way info is presented to the senses)
- **Interactivity**
  - The extent which users can participate in modifying the form and content of a virtual environment in real time

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



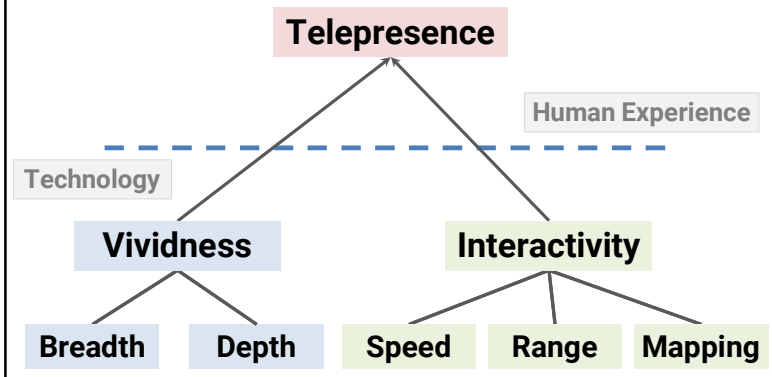
Factor of Vividness (cont.)

- **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



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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**

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Head-mounted Display

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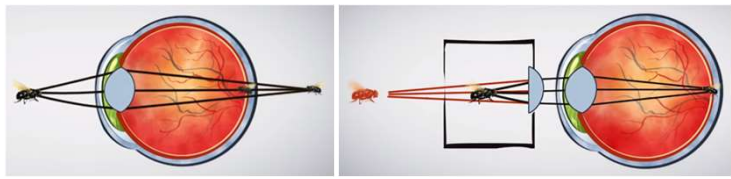
Head-mounted Display

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



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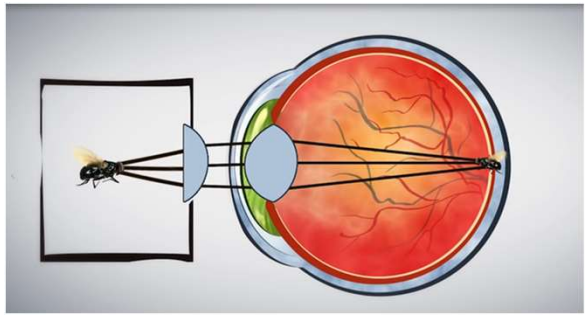
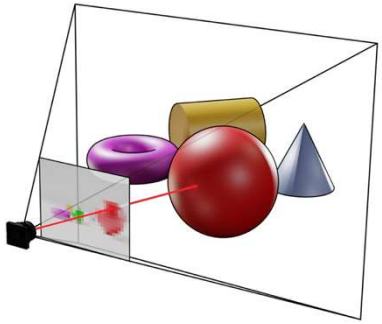
Head-mounted Display (cont.)

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



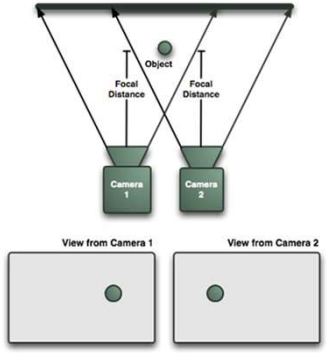
Stereo Simulation

- Based on binocular display



Stereo Simulation (cont.)

- Based on binocular display



Stereo Simulation and Rendering

Stereo Simulation, Rendering, and Display

Tracking System

- Degree of freedom

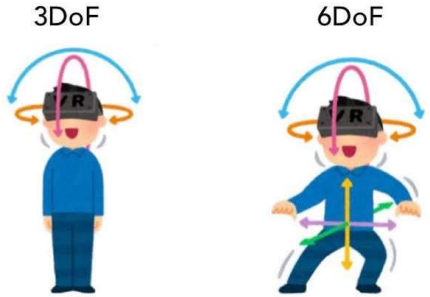
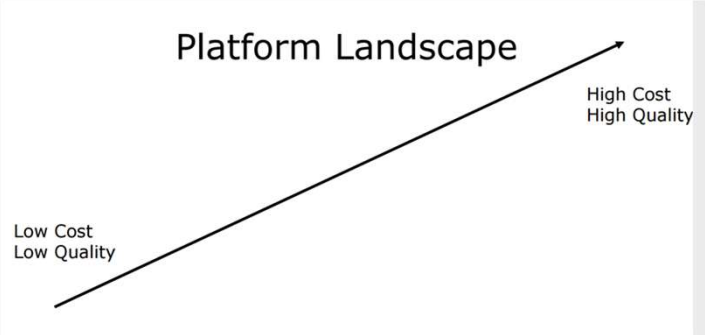


Image from
https://toast.games/4-things-to-know-about-vr-before-you-buy-a-headset/

Tracking System (cont.)

- VR devices in 2016

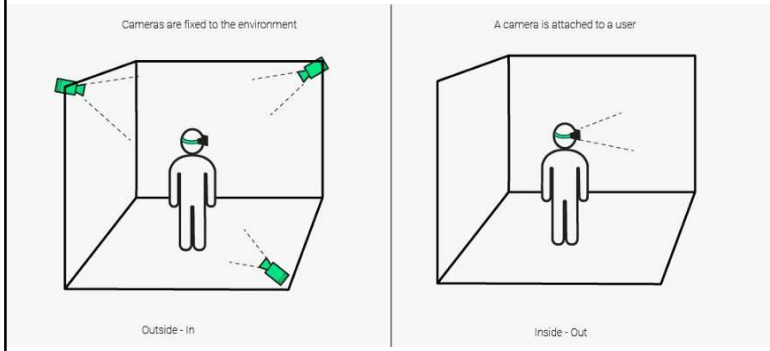


Tracking System (cont.)

- VR devices in 2016

Tracking System (cont.)

- Two types of tracking systems



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Outside-In Tracking

Oculus Rift

Constellation

HTC Vive

Lighthouse

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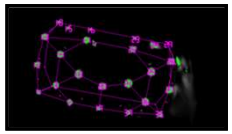
Oculus Rift: Constellation

- 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)



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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

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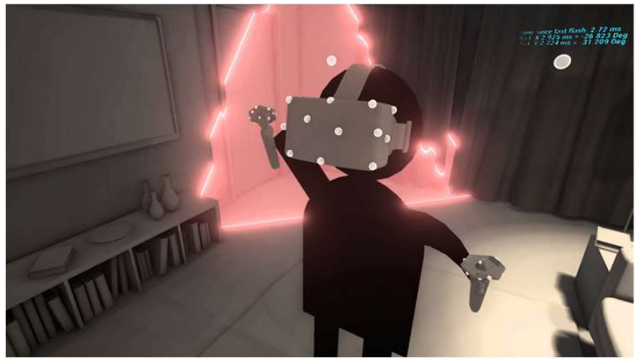
HTC VIVE: Lighthouse (cont.)

- https://youtu.be/J54dotTt7k0



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Inside-Out Tracking

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

Oculus Quest (May, 2019)

HTC VIVE Focus Series

Oculus Quest 2 (Oct. 2020)

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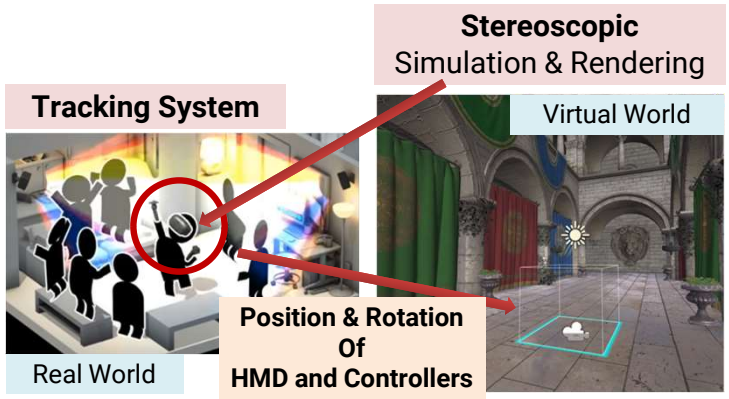
Put It All Together



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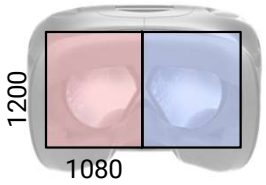
Major Challenges

- 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

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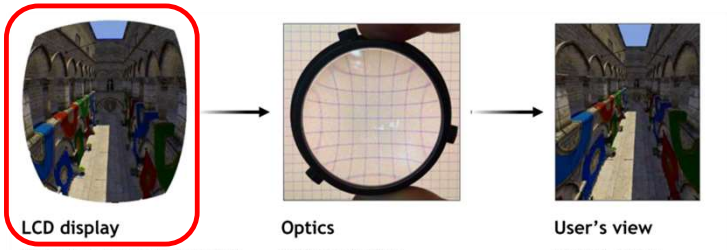
Major Challenges

- 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



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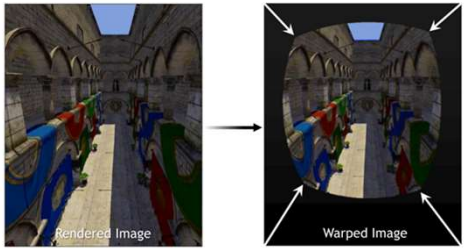
Major Challenges

- 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



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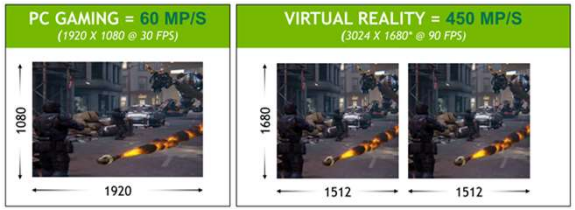
Major Challenges

- Rendering cost
  - Rendered pixel per second



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

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Major Challenges

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

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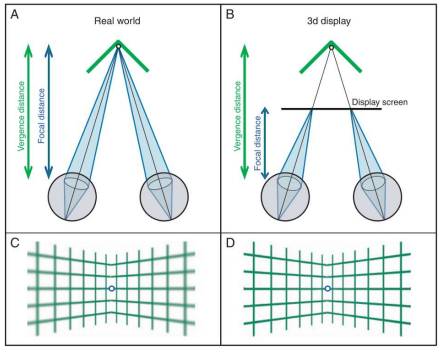
Major Challenges

- Motion sickness



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Major Challenges

- Motion sickness

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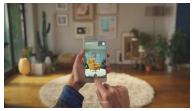
Extended Reality

real environment — **virtual environment**

Augmented Reality (AR)



Mixed Reality (MR)

Virtual Reality (VR)

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Extended Reality

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

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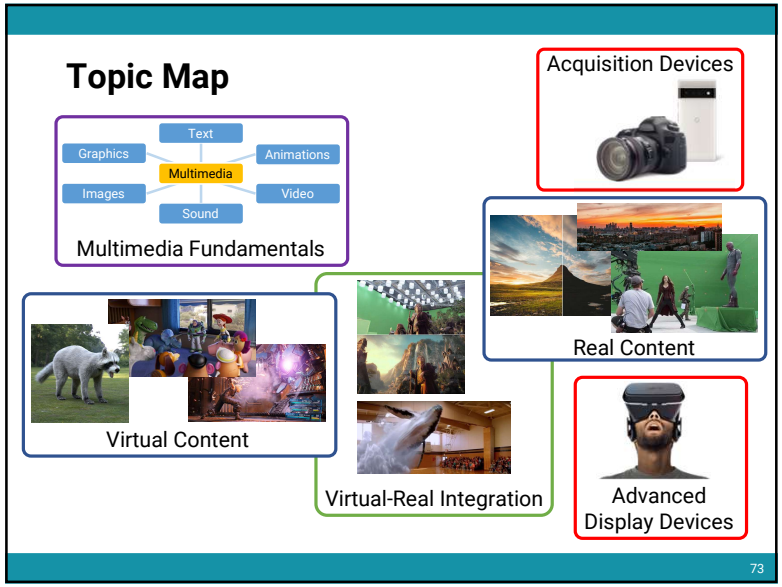
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Real Content
Virtual Content
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Display Devices
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