Fundamentals of Extended Reality

Goals

Why does extended reality work?

How does extended reality work?

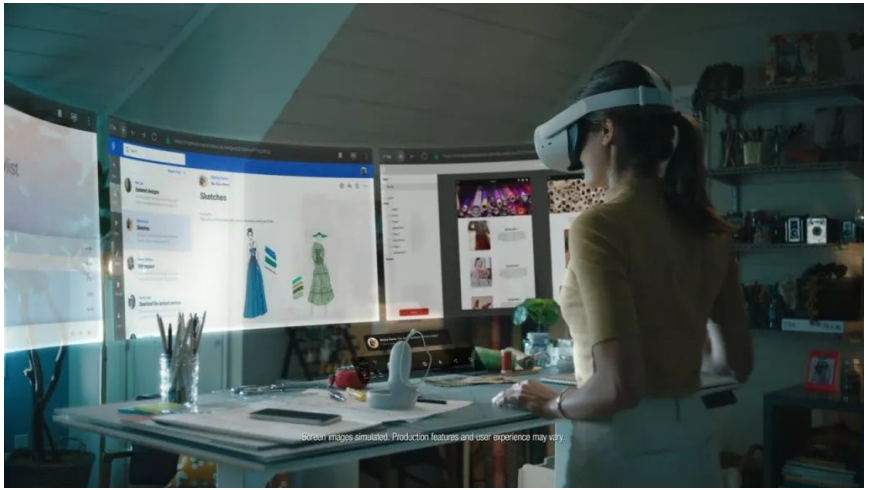
XR System Form Factors

Form Factor	Simulated Environment	PC Tethered	All-in-One	Mobile/ Smartphone
Cost	Very High	PC Dependent	Medium	Low
Fidelity	Very High	High	Medium	Low
Motion Tracking	Very High	Very High	Medium	Low
User Input	Realistic	High	Medium	Low

Overlay Physical Space (OPS)

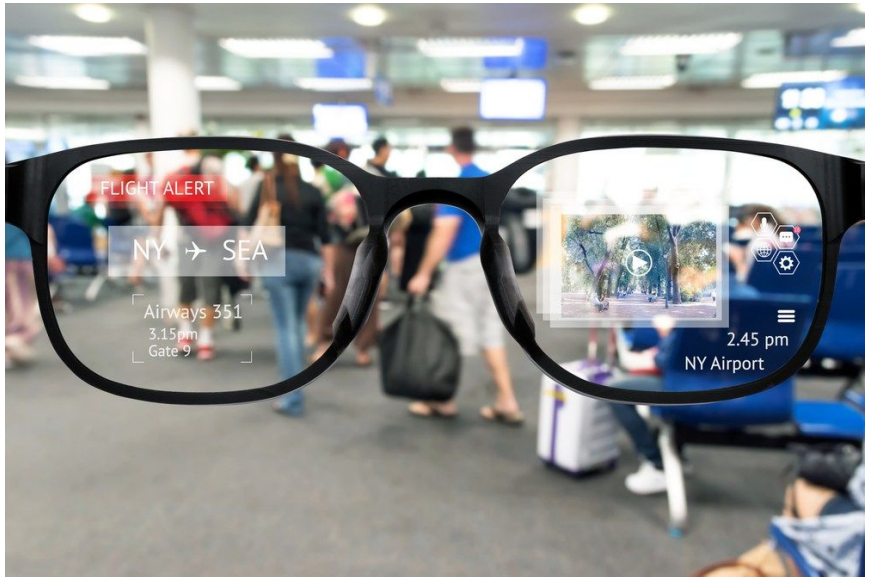
- Overlay Physical Space models and coincides with the real world
  - Hololens, Wearable VR
- Interacting with OPS objects implies interacting with the real world.
- OPS is anchored at a fixed 3D location.
- OPS can be shared and manipulated by multiple users.

Egocentric User Space (EUS)



- Egocentric User Space is an immersive virtual space with its origin anchored from the user's perspective and typically moved with the user's movement.
- Typically, user interaction in EUS is projected within an arm's reach
  - Hand gestures
  - controllers
- Shared EUS content, such as video calls, is rendered individually for each user.

Near-Eye Display Space (NDS)



- Near-Eye Display Space renders 2D menu and items on head-mounted displays
  - Google glass
- Content is not anchored to any physical objects.
- User interactions in NDS:
  - Gaze
  - 2D Touch
- NDS reserved for sharing private system informations, rarely shared between users.

Extended Reality Process

How is augmented and virtual reality processed?

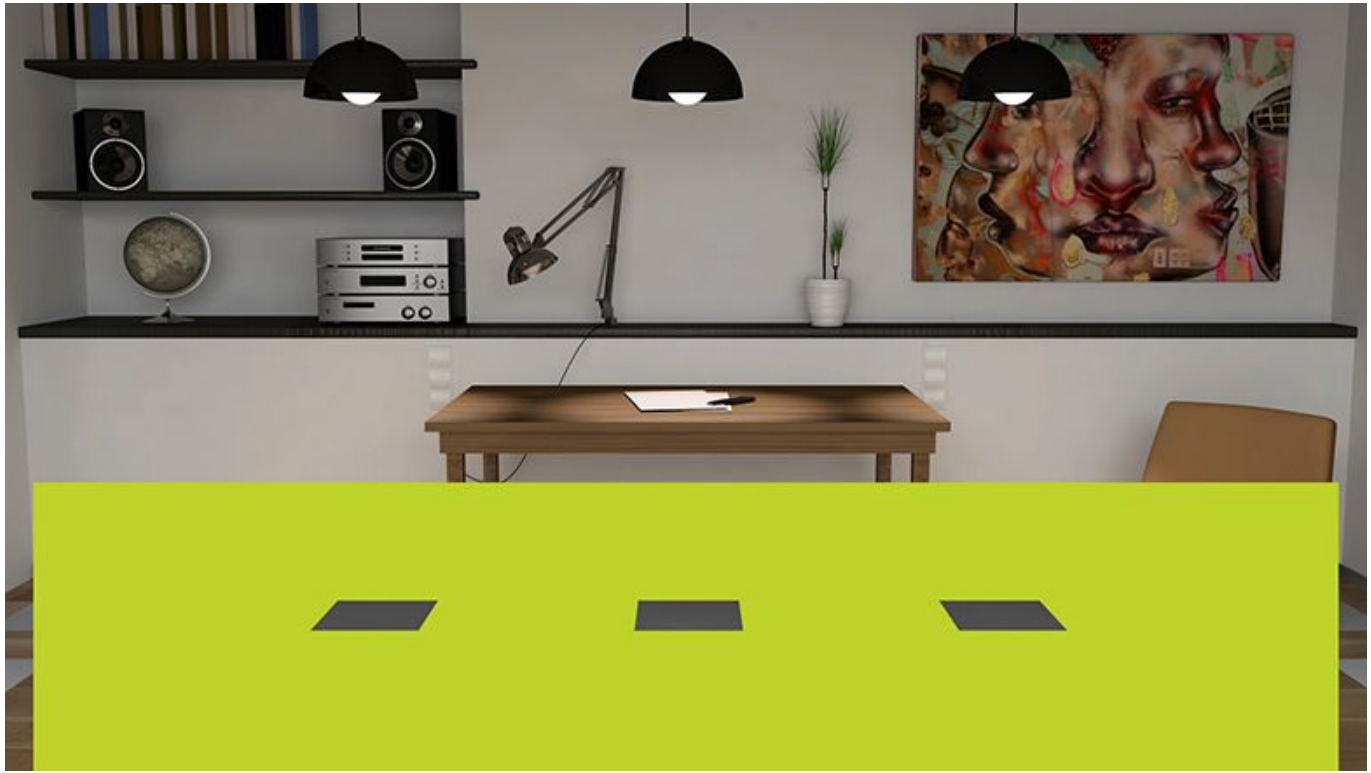
Four main stages:

- Scene Capture
- Identification
- Processing
- Preview

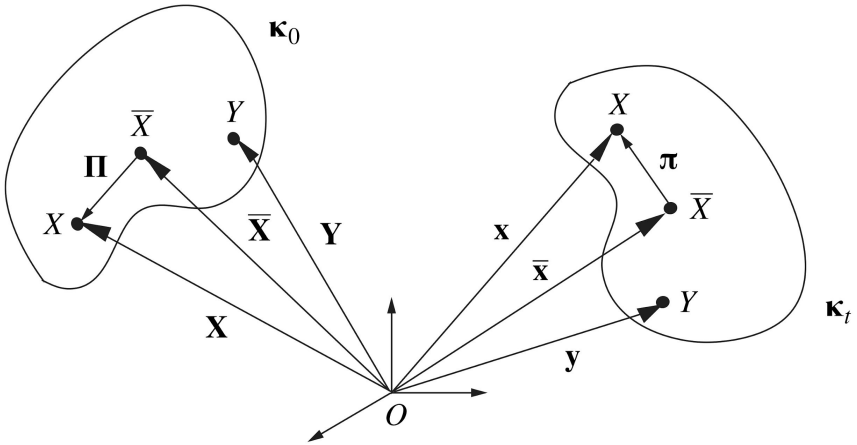
Core Idea

The key to creating an immersive virtual reality experience is in giving our senses the correct perceptual inputs.

Illusion



Rigid Body Motion (Body Tracking)



- Definition: A **rigid body** defines a set of 3D points, whereby for any two points p and q, the distance between them is always constant

$$\left\| \begin{bmatrix} x_p \\ y_p \\ z_p \end{bmatrix} - \begin{bmatrix} x_q \\ y_q \\ z_q \end{bmatrix} \right\| \equiv \text{constant}$$

- A **rigid-body motion** is a 3D transformation $g : \mathbb{R}^3 \to \mathbb{R}^3$ that maps all the points on a rigid body, and the motion does not violate the above rigid-body constraint:

$$\left\| g\left(\begin{bmatrix} x_p \\ y_p \\ z_p \end{bmatrix}\right) - g\left(\begin{bmatrix} x_q \\ y_q \\ z_q \end{bmatrix}\right) \right\| \equiv \left\| \begin{bmatrix} x_p \\ y_p \\ z_p \end{bmatrix} - \begin{bmatrix} x_q \\ y_q \\ z_q \end{bmatrix} \right\|$$

Immersion

Immersion: the objective level of fidelity of sensory stimuli produced by a VR system.

Immersion

Optical Perception (Sight)

Auditory Perception (Sound)

Haptic Perception (Touch)

Smell

Taste

Proprioceptive Perception (Balance and Movement)

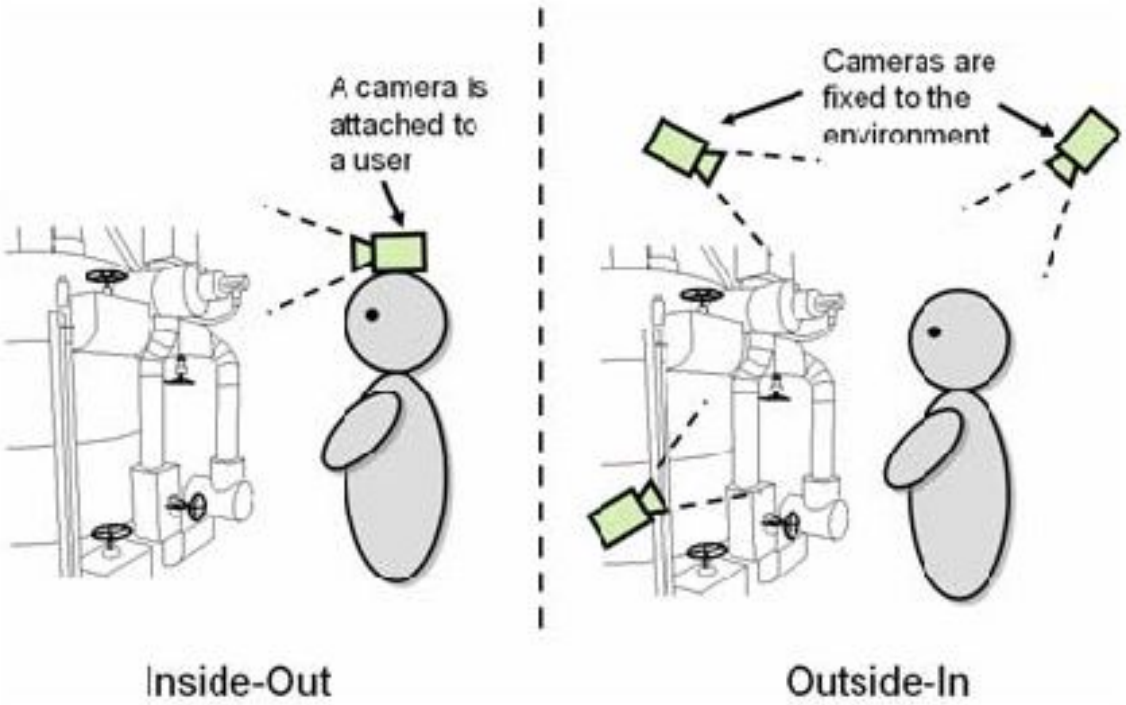
Optical Perception

Factors affecting Optical Immersion

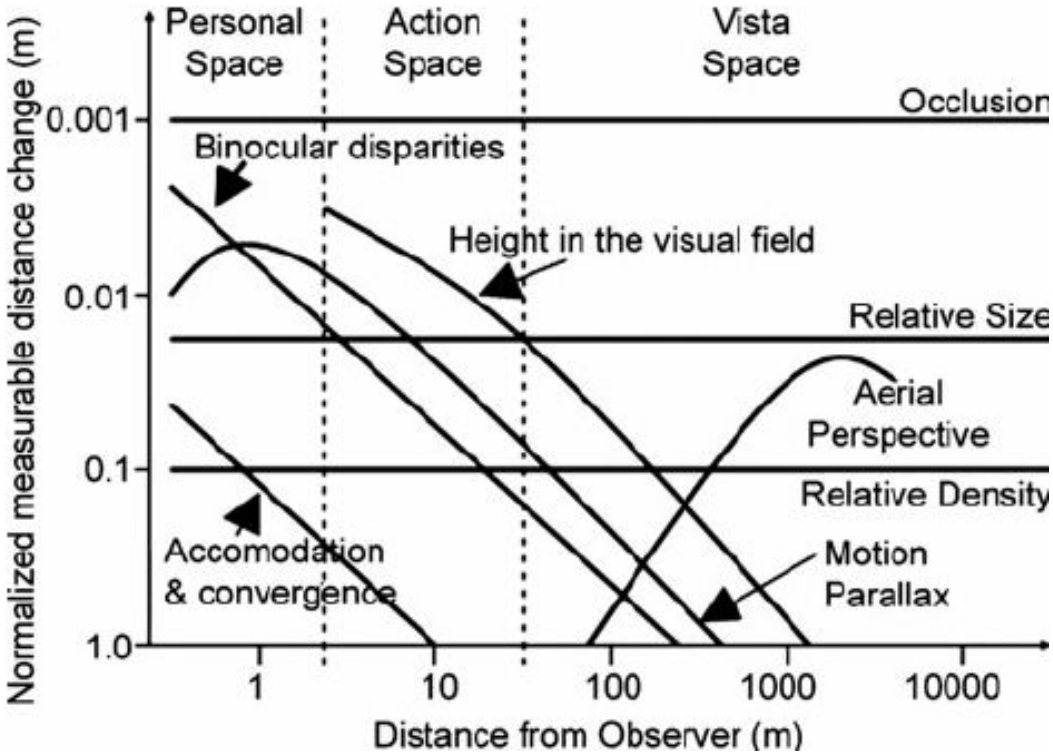
Visual immersion:

- Consistent graphics
- High FOV
- High resolution display
- High frame rate
- Realistic lighting
- **Head-based rendering**
- **Depth cues**

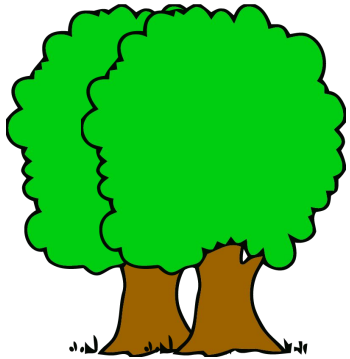
Tracking

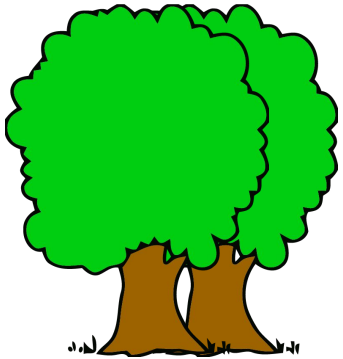

A camera is attached to a user
Cameras are fixed to the environment
Inside-Out
Outside-In

Depth cues

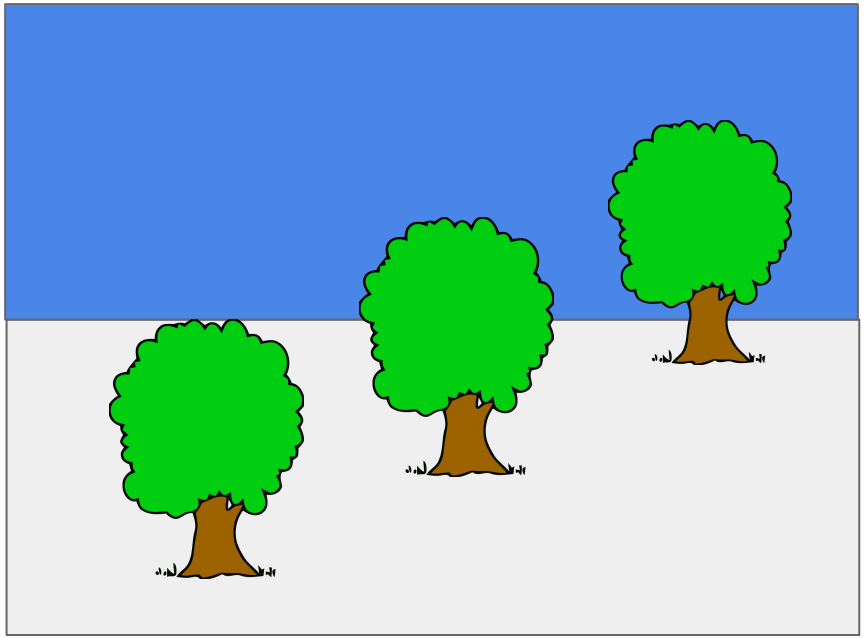

Personal Space
Action Space
Vista Space
Occlusion
Binocular disparities
Height in the visual field
Relative Size
Aerial Perspective
Relative Density
Motion Parallax
Accomodation & convergence
Normalized measurable distance change (m)
0.001
0.01
0.1
1.0
1
10
100
1000
10000
Distance from Observer (m)

Occlusion



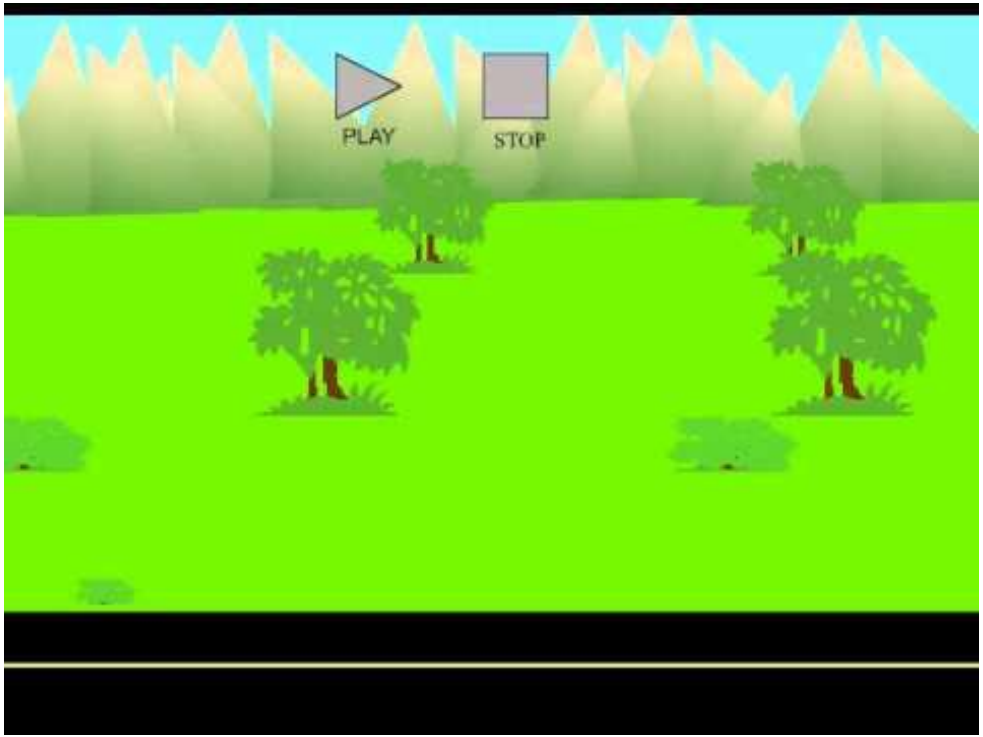


Height in the visual field

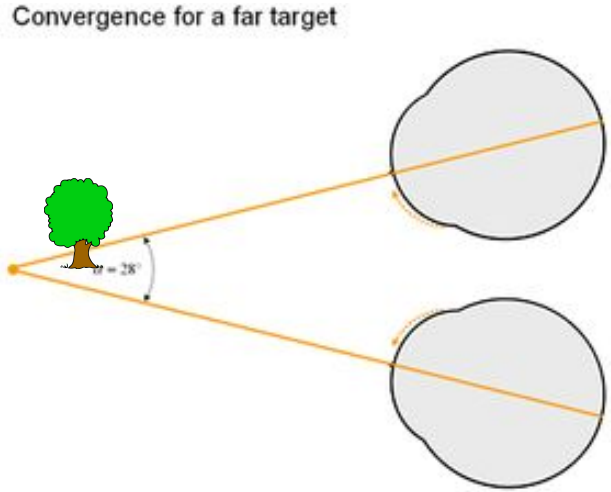


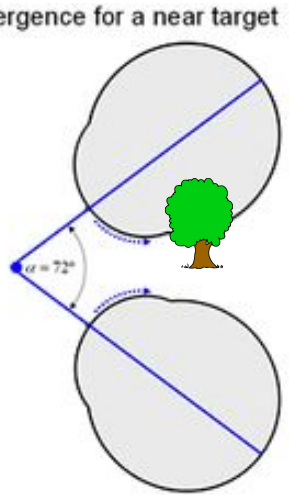
Relative size

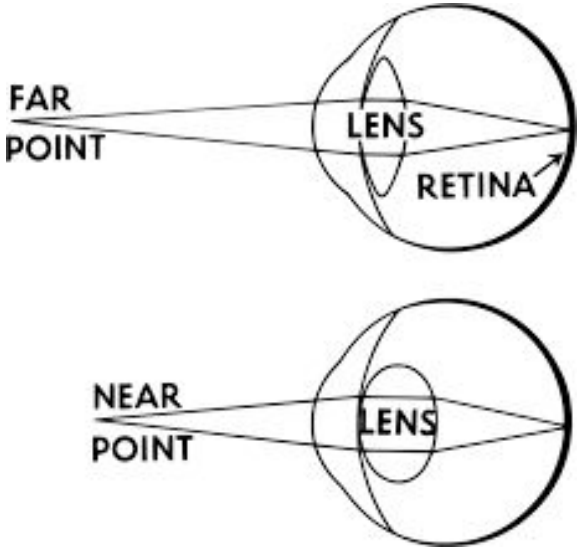
Motion Parallax



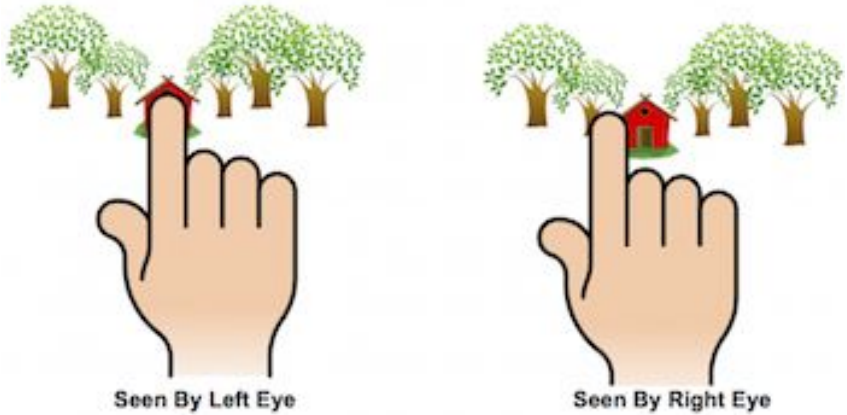
Accommodation and convergence







Depth cues -
Binocular disparity



Depth cues - Binocular disparity

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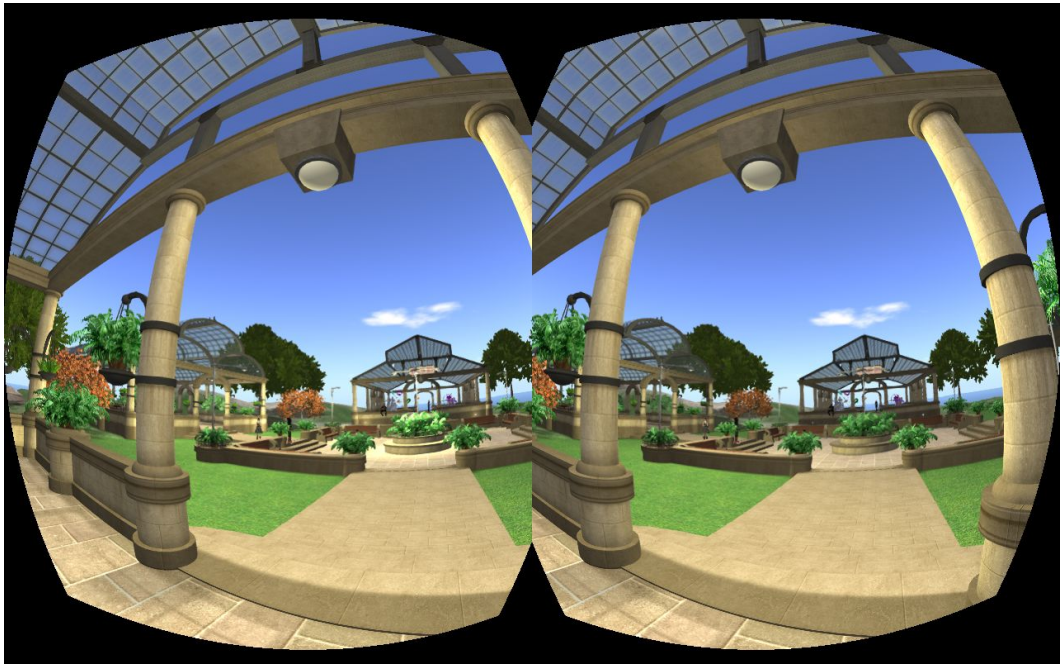
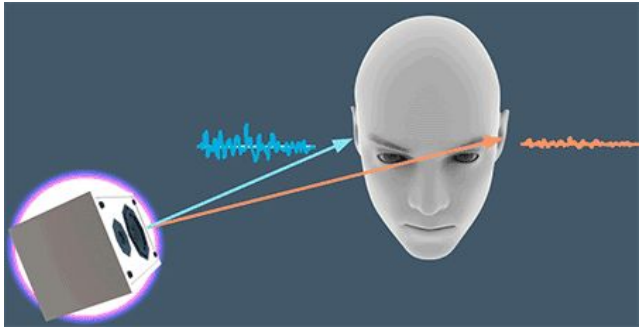


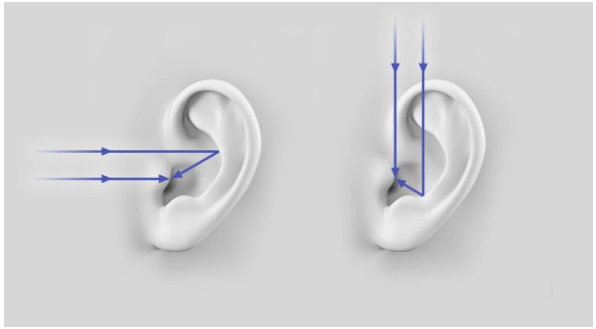
Auditory Perception

Spatial Audio

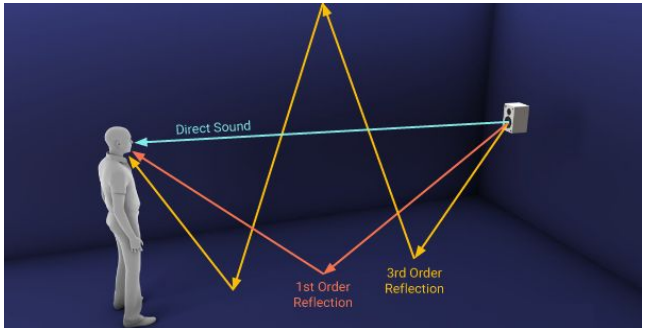
Inter-aural timings



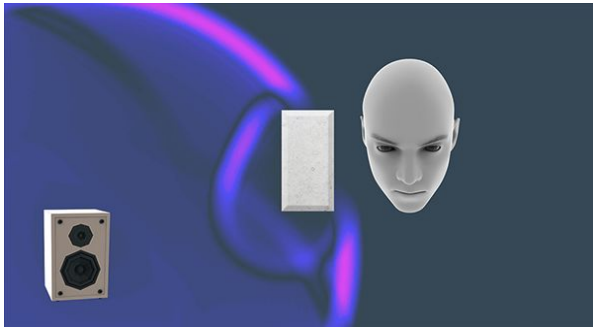
Spectral filtering



Reverb

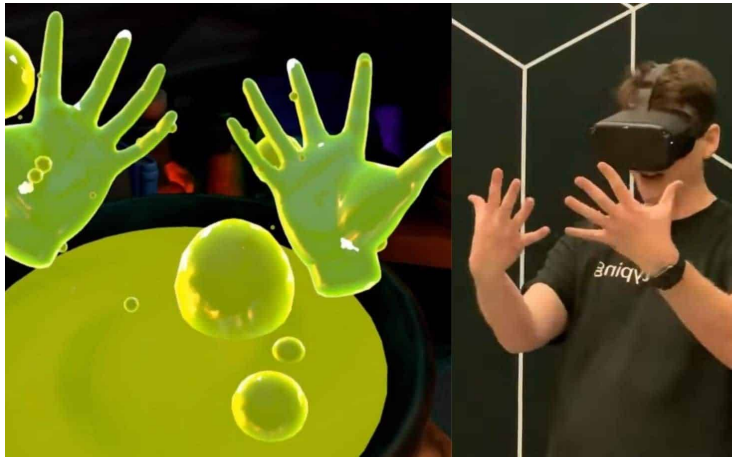


Occlusion and Diffusion



Haptic Perception

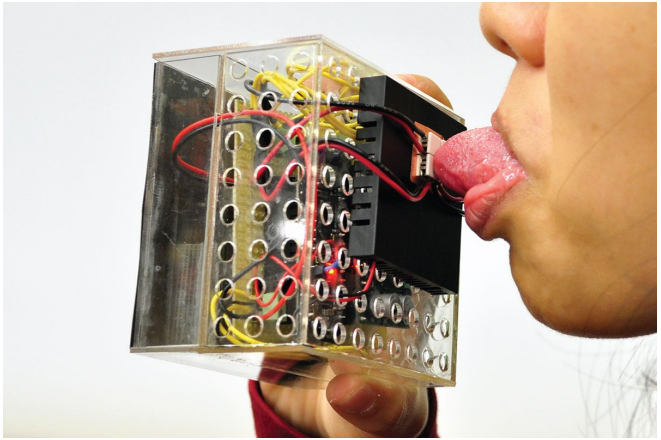
Hand tracking

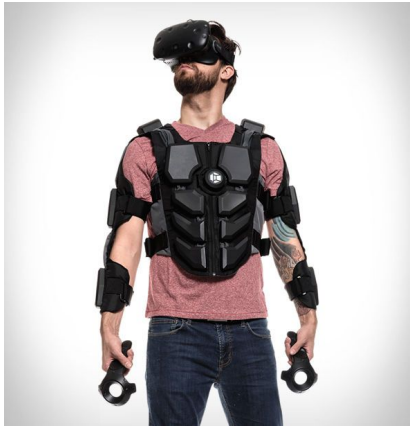


Putting it all together

Putting it All Together

More immersion?





Presence

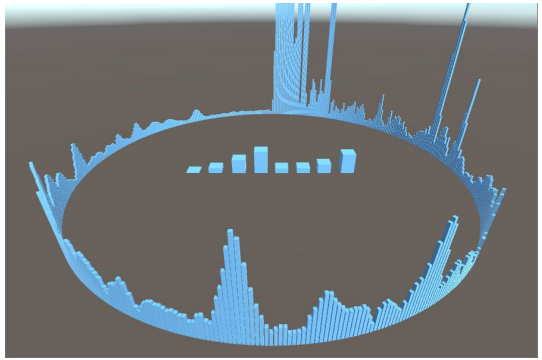
Presence: The illusion of unmediatedness.

The subjective sense of “being there”.

Covered in future lectures...

Homework and Lab

- HW2 has been officially assigned, due **night before next class**
  - Build music visualizer!
  - Find it on the class website!
  - ***Start Early!!!!!!!!!***
- Lab 1
  - Find the lab at **xr.berkeley.edu/decal**
  - **Lab checkoff = attendance**
  - If you don't finish lab, we will check off if effort was made



Oculus Login

Don’t login using Meta account, login using Oculus.

- User: xratberkeley@gmail.com
- Password: ThisIsMyUmbrella

Oculus