Hardware and Input Schemes

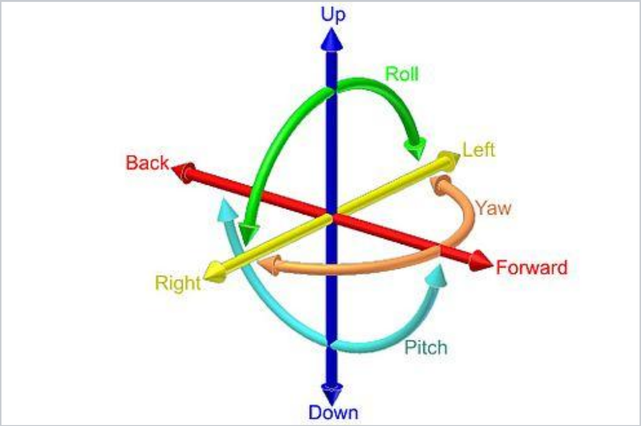
Goals

1. Tracking technologies
2. Hardware types
3. Input schemes

Tracking Technologies

Degrees of Freedom (DoF)

- **Definition**: the extent to which the hardware allows a person to move in 3D
  - Translational and rotational
  - Defines the interactivity of a VR system

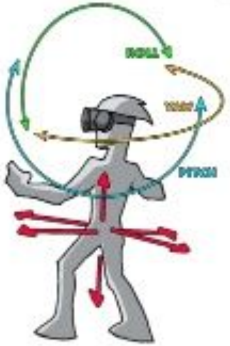


3-DoF vs 6-DoF

3 degrees of freedom (3-DoF)

- "In which direction am I looking"
- Detect rotational head movement
- Look around the virtual world from a fixed point

6 degrees of freedom (6-DoF)



- "Where am I and in which direction am I looking"
- Detect rotational movement and translational movement
- Move in the virtual world like you move in the real world

Tracking Technologies

3-DoF

- Inertial Measurement Units (IMUs)
  - Gyroscope
  - Accelerometer
  - Compass

6-DoF:

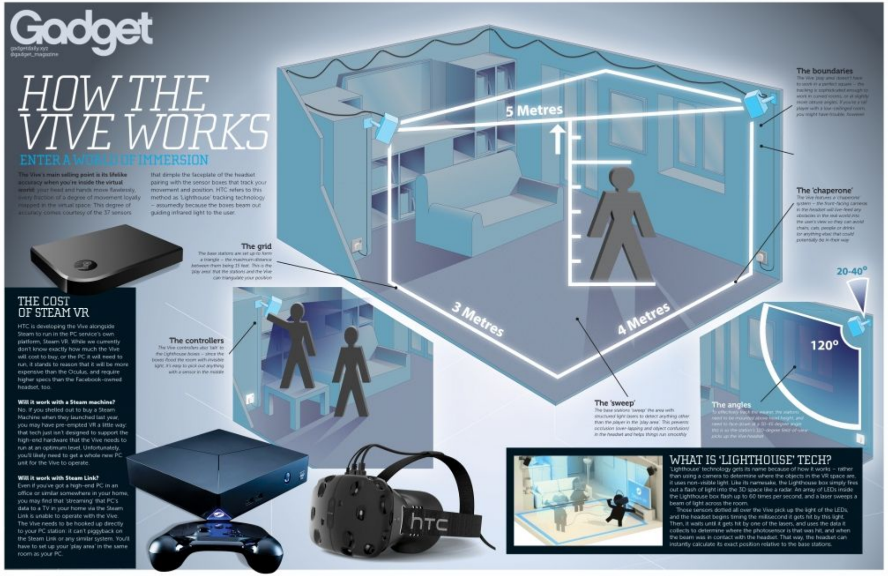
- Outside-In
  - Lighthouse (HTC Vive)
  - Constellation (Rift)
- Inside-Out
  - Insight (Quest)

Outside-In: relies on fixed external hardware

Inside-Out: sensor hardware internal to headset

Lighthouse (HTC Vive)

- Lighthouse(s) send out sweeping, infrared (IR) lasers
- Sensors on headset & controllers pick up IR at different times
- Computer determines 6-DoF from time delay



Constellation (Rift)

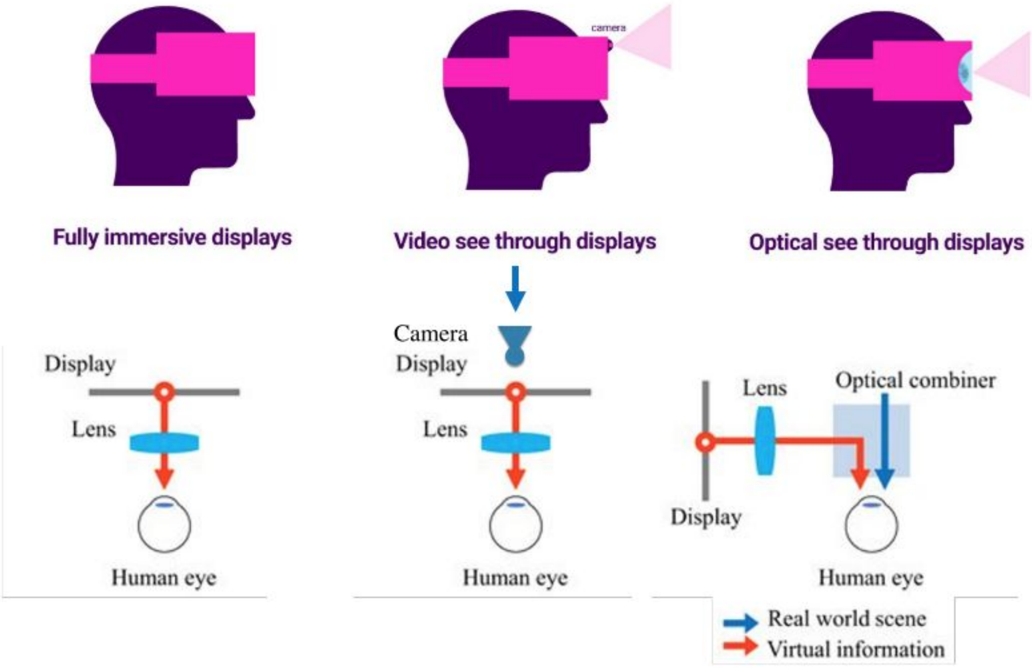
- Headset and controllers flash IR lights
- Sensors detect IR
- Computer uses computer vision (CV) to determine 6-DoF

Insight (Oculus Quest + Rift S)

- New direction for stand-alone (and other) headsets
- Camera(s) are distributed across headset
- Headset views surroundings, uses CV to track player in 6-DoF

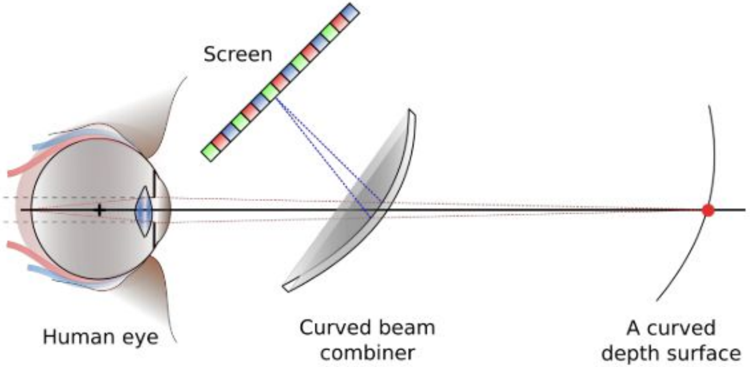
Hardware Types

Head-Mounted Displays



Meta 2

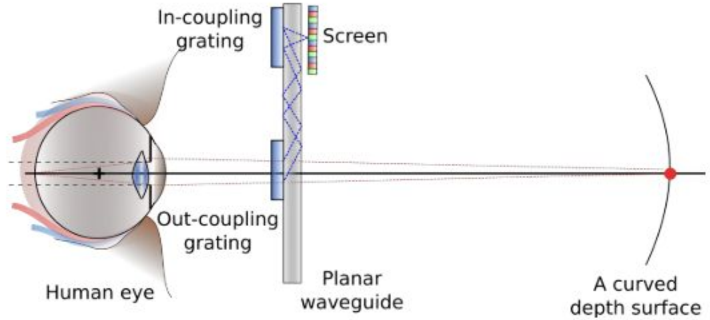
Off-axis curved beam combiner

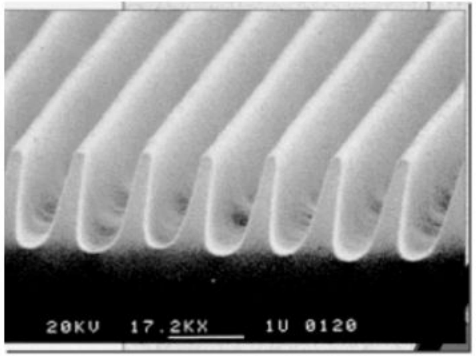


Microsoft HoloLens

(also Magic Leap One, Sony Smart Eye)

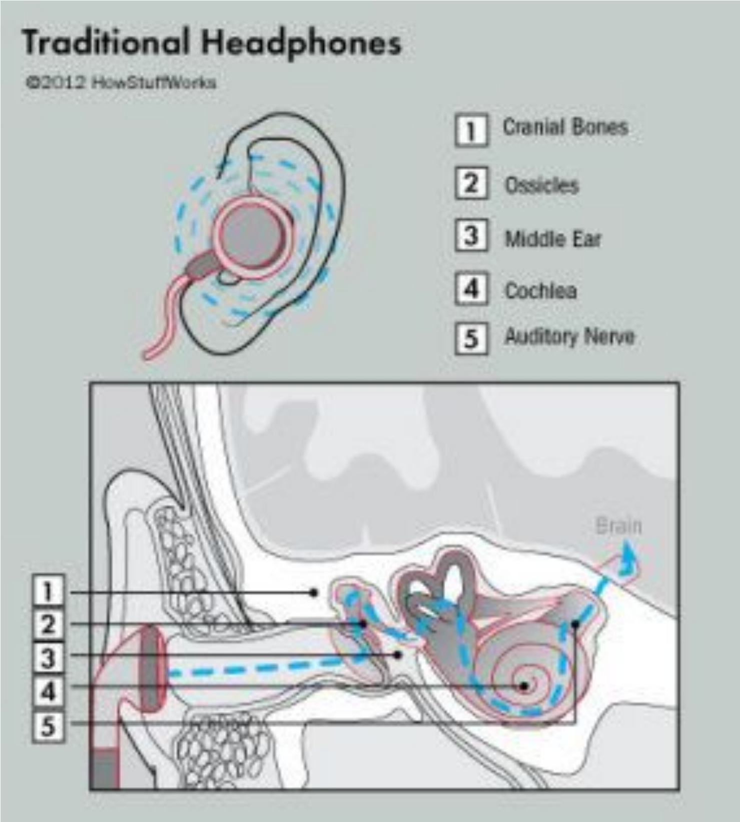
Diffractive waveguide

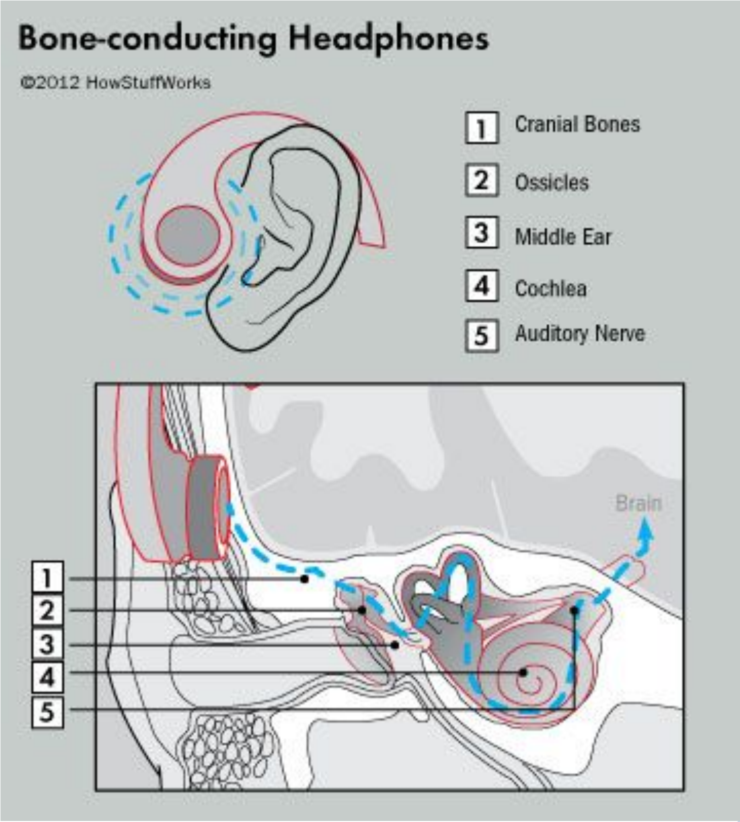




Research Topics in Near-Eye Displays

- Addressing the vergence-accommodation conflict (VAC): varifocal displays, multiplane displays, light field displays
- Addressing the bandwidth bottleneck with foveated rendering
- Vision-correcting near eye displays


Traditional Headphones
©2012 HowStuffWorks
1 Cranial Bones
2 Ossicles
3 Middle Ear
4 Cochlea
5 Auditory Nerve
Brain
1
2
3
4
5

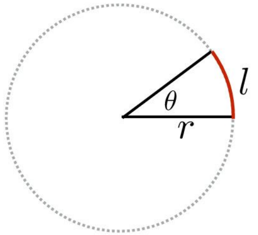

Bone-conducting Headphones
©2012 HowStuffWorks
1 Cranial Bones
2 Ossicles
3 Middle Ear
4 Cochlea
5 Auditory Nerve
Brain
1
2
3
4
5

- **PPI = pixels per inch**
  - Perceived resolution depends on viewer's distance
  - "Retina display" -> 300PPI at 10 inches
- **PPD = pixels per degree**
  - Degree of solid angle subtended (#pixels/FOV)
  - Distance independent measurement

Angles and Solid Angles

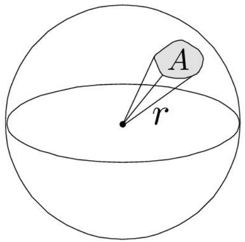
Angle: ratio of subtended arc length on circle to radius

- $\theta = \frac{l}{r}$
- Circle has 2π radians



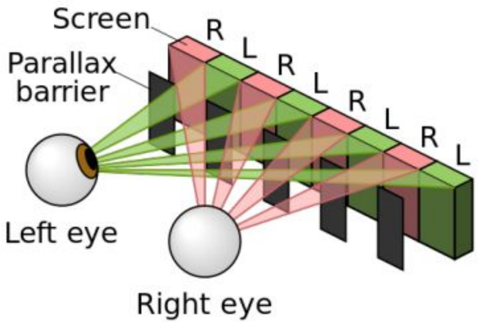
Solid angle: ratio of subtended area on sphere to radius squared

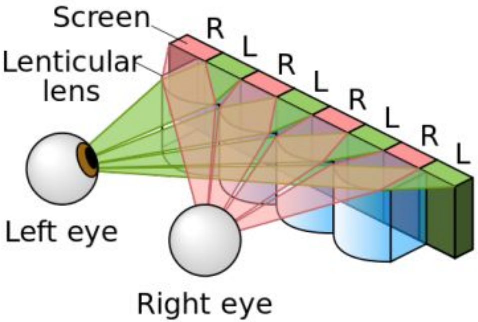
- $\Omega = \frac{A}{r^2}$
- Sphere has 4π steradians



Auto-stereoscopic Displays

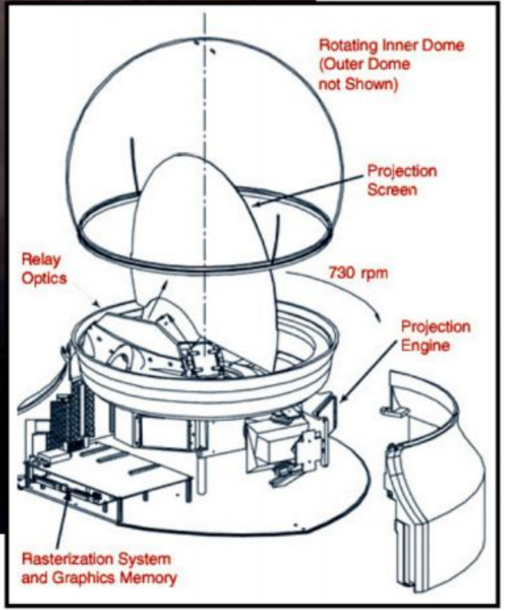
- stereo 3D viewing without special glasses or HMDs
- Parallax barrier (nintendo 3DS), lenticular displays
- Volumetric displays





Volumetric Displays

Actuality Perspecta



Haptic Displays

- Perceptual dimensions
  - tactile cues: vibrations, static relief shapes, direct electrical stimulation
  - kinesthetic cues: force feedback displays, haptic brake displays
- Resolution
  - spatial resolution
  - temporal resolution (>=1kHz)
- Ergonomics: safety, comfort

Haptic Display Types

- ground-referenced
- body-referenced
- tactile
- in-air
- combination
- passive

Ground-Referenced Devices

Force Feedback wheels

Force Feedback joystick

Ground-Referenced Devices

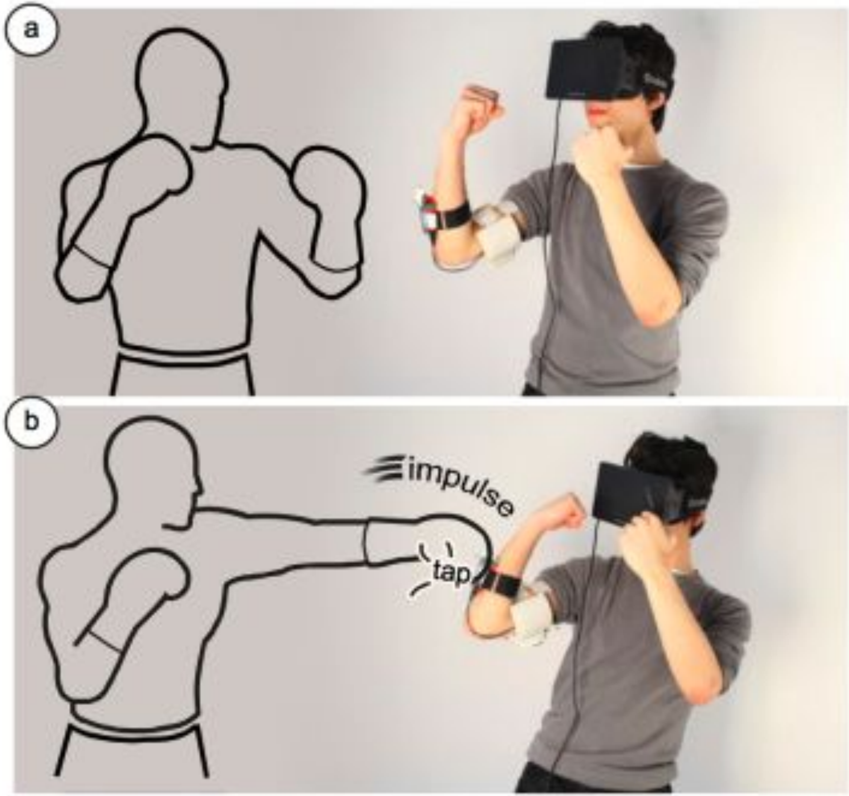
SensAble / 3D Systems Phantom

Body-Referenced Devices

Follmer Lab

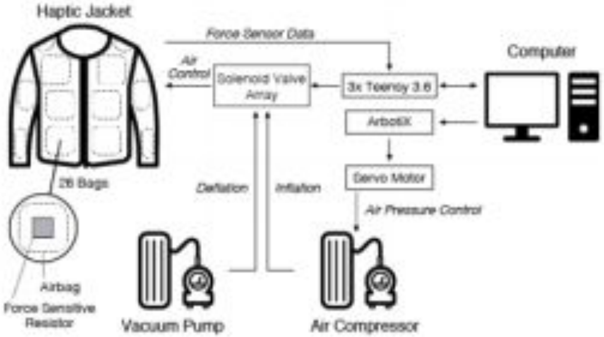
Immersion

Body-Referenced Devices



Impacto, Lopes et al. Video: https://youtu.be/k5e4mXQLq54

Body Referenced: Force Jacket



Delazio et al, CHI 2018

Headsets and Degrees of Freedom (DOF)

Controllers

	3-DoF	6-DoF
0-DoF	Google Cardboard / Gear VR	Oculus DK2
3-DoF	Oculus Go	Vive Focus
6-DoF	Google Daydream	HTC Vive, Oculus Rift...

0 DoF Controller / 3 DoF Headset

- Hardware: Google Cardboard, Gear VR
  - *Pros*: Cheap, highly accessible
  - *Cons*: Low interactivity & immersion

	3-DoF	6-DoF
0-DoF		
3-DoF		
6-DoF		

6 DoF Controller / 6 DoF Headset

- Hardware: Valve Index, Oculus Quest 2, etc.
  - *Pros*: Best level of interactivity/immersion
  - *Cons*: Expensive, heavy setup

	3-DoF	6-DoF
0-DoF		
3-DoF		
6-DoF		

Other Categories

- As DoF increases:
  - *Pros*: Functionality, interactivity increases
  - *Cons*: Cost, resources needs increase

	3-DoF	6-DoF
0-DoF		
3-DoF		
6-DoF		

Input Schemes

Input Schemes

Gaze control

Eye tracking

Clickers

Tracked controllers

Hand tracking

Gloves

- Track headset position and rotation as input
  - *Pros*: Works well without additional equipment or technology
  - *Cons*: Slow & delayed input, limits head movement

Input Schemes

- Gaze control
- **Eye tracking**
- Clickers
- Tracked controllers
- Hand tracking
- Gloves

- Track eye gazing direction for input
  - *Pros*: Hands free, enables foveated rendering
  - *Cons*: Under development, restricts eye movement

Input Schemes

- Gaze control
- Eye tracking
- **Clickers**
- Tracked controllers
- Hand tracking
- Gloves

- Point and click
  - *Pros*: Easy to use
  - *Cons*: Low immersion / interactivity

Input Schemes

Gaze control

Eye tracking

Clickers

Tracked controllers

Hand tracking

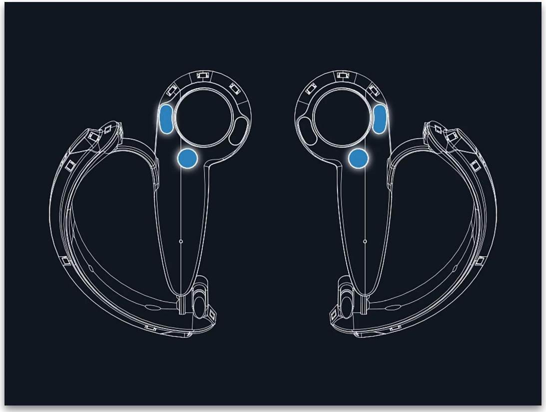
Gloves

- Specialized controllers for VR (Rift, Vive, Quest, etc.)
  - *Pros*: Great immersion / interactivity
  - *Cons*: High maintenance, dependent on sensors

Input Schemes

- Gaze control
- Eye tracking
- Clickers
- **Tracked controllers**
- Hand tracking
- Gloves

- Specialized controllers for VR (Rift, Vive, Quest, etc.)
  - *Properties*:
    - Ergonomics
    - Hand estimation
    - Expressiveness



Input Schemes

- Gaze control
- Eye tracking
- Clickers
- Tracked controllers
- **Hand tracking**
- Gloves

- Track hand poses/motion for input (Leap Motion)
  - *Pros*: Very intuitive and natural input system
  - *Cons*: No haptic or force feedback
    - E.x. pushing a button

Input Schemes

Gaze control

Eye tracking

Clickers

Tracked controllers

Hand tracking

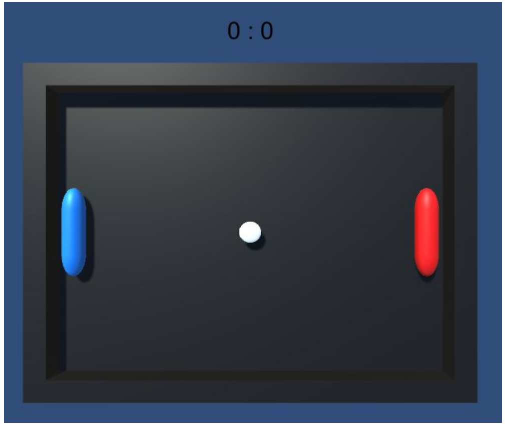
Gloves

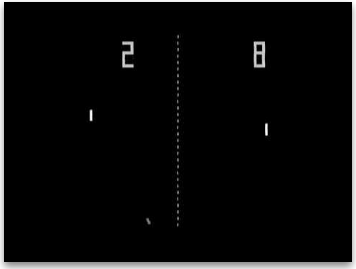
- Augmented gloves for pose tracking and movement
  - *Pros*: Adds “touch” to VR, more robust tracking
  - *Cons*: Under development, force feedback difficult

Homework and Lab

- **HW4** has been officially assigned, due **the night of next class**
  - Build the classic game of Pong.
  - Find it on the class website!
- Next week will be **design principles** and **VR applications**

Find lab 3 at **xr.berkeley.edu/decal**





Homework Submission Update